Harrison, McClain & Parmely

Re-design of gas power plant of Hoopeston, Illinois

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RE-DESIGN OF GAS POWER PLANT OF HOOPESTON, ILLINOIS

BY

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THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

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D. F. HARRISON
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F. H. McCLAIN

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May 31 1909

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Donald Frederic Harrison and James Clyde Parmeley

ENTITLED Re-design of Gas Power Plant of Hoopeston, Illinois

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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DEGREE OF Bachelor of Science in Electrical Engineering

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P R E F A C E.

Knowledge of the existing conditions presented to the authors the need of extensive improvements in the electric lighting and power service in the city of Hoopeston, Illinois. An increasing load requires additions to the present equipment of the power plant; its unsatisfactory arrangement and poor foundations demand a redesign; and the acquisition of a larger and more desirable site due to the installation of a gas plant warrants the removal of the power station to the new location. The following is a complete analysis of the present and an investigation of the probable future conditions with what appeared to them to be the most logical improvements.

Thanks are due to Mr. C. E. Bryson, Manager, Mr. W. C. Glendenning, Chief Engineer, and other employees of the Hoopeston Gas and Electric Company for their hearty cooperation and assistance in the tests and collection of data pertaining to the electrical distribution.

The Authors

I N T R O D U C T I O N.

The Hoopeston Gas and Electric Company furnishes electric current for private, commercial and street lighting and for power uses in the city of Hoopeston, Illinois. This is a city of 6000 inhabitants situated at the intersection of the Chicago and Eastern Illinois and Lake Erie and Western railroads about twenty-four miles north of Danville, Vermilion County, Illinois. The diversified manufactories located within its limits make this city more of an industrial center than the average town of its size.

This company is at present confronted with the problem of enlarging their plant to care for the increasing load they have experienced during the past winter. The present equipment does not provide for a reserve unit on the heaviest loads and the sizes of the units unfortunately are not suited to the power demands. The company has recently acquired a new site, located as shown upon the map, page 69, for the erection of a gas plant and has wisely decided to remove the present equipment to a new building upon this property. The new building will allow a more satisfactory arrangement of the apparatus and provide new and better foundations. The soil at Hoopeston is of such a character that it is particularly unsatisfactory for engine foundations. This is caused by an underlying strata of blue clay of about the consistency of dough. The foundation of the 280-horsepower engine

was built upon this soil and is not sufficiently large to prevent vibrations.

The original installation in this building consisted of high-speed steam engines belt-connected to alternating current generators. This equipment was badly overloaded and was allowed to get into such condition that the service became very poor. The company sought to remedy this by installing a 280-horsepower suction gas engine and producer outfit in June, 1908, but, unfortunately, the unskilled attendants were unable to handle this machinery properly with the result that the service grew worse and the gas engine was allowed to follow in the wake of its predecessor. The services of a competent gas engine operator were secured early in 1909 and the service was improved to such an extent that the company decided to install another 100-horsepower gas engine in June, 1909, and discard the old steam equipment entirely. Since this time the service has improved steadily.

DESCRIPTION OF PLANT:-

The power house of the Hoopeston Gas and Electric Company is located in the northwest corner formed by the intersection of the Chicago and Eastern Illinois and the Lake Erie and Western railroad tracks, as shown upon the map, page 68. The ground is low and very poorly drained. A tile laid twelve feet below the surface completely around the building provides the only drainage. This tile empties into a well sunk for this purpose and to receive the gas engine jacket water and cool it before it is re-pumped into a tank upon the roof of the coal bin, from where it feeds into the jackets by gravity.

Building:

The building is an old one, built to house the old steam engine installation, and is in very poor condition. The roof is of tarred paper and leaks freely in several places. The last engine was installed just beyond the building and a temporary shelter was built over it. No floor was laid in this addition. The arrangement of the rooms is as shown in Fig. 1, page 70. The producers were installed in one side of the old boiler room, one boiler being removed to make room for them, and a concrete floor surrounds them. The floor of the engine room is concrete with the exception of places left vacant by the removal of the former installation, which are laid with brick. The walls are constructed of brick and are in very poor condition.

Foundations:

The arrangement of the units is also shown by Fig. 1, page 70. As illustrated, the engines are belt-connected to their respective generators and the exciters, in turn, are belted to the generator shafts. The foundation under engine No. 1 was improperly constructed and the engine rocks considerably with each explosion, causing a decided flop in the belt. This foundation is rectangular in shape, without the customary sloping sides, and has a cross sectional area only slightly larger than the bottom of the engine frame. One corner, the northeast, has settled more than the remainder of the foundation. The poor condition of the foundation undoubtedly accounts for the trouble that has been experienced with the bearings of this engine and this trouble will probably only be remedied by installing a new foundation. The attempt was made to tie this foundation to the one installed with the small

unit in June, 1909, but was unsuccessful. The foundation of the small unit is satisfactory in every way. This foundation is somewhat larger proportionately than the first, has properly sloping sides and is connected in front with the generator foundation.

Producers:

The equipment of the plant consists of two Muenzel gas engines of 280- and 100-horsepower, respectively, two producers of the same make and Westinghouse electrical machinery. As shown in Fig. 4, page 73, one wet and one dry scrubber are used for both producers, the producers being connected into a common main. The producers, which are of the suction type, are rated at 150-horsepower each. A vertical section through the producer is shown in Fig. 5, page 74. The air supply is taken from the room near the level of the tops of the producers down through a preheater, P, into the ashpit, A. This preheater consists merely of a space around the gas pipe, G, enclosed by sheet iron so that the comparatively cool ingoing air is heated by the hot outgoing gases. Steam from the vaporizer, V, is admitted through a valve, M, that may be regulated by hand, and mixes with this air in the preheater. The air and steam enter the ashpit of the producer and from thence pass up through the fuel bed, B. The vaporizer, V, is in the shape of a pan forming the top of the producer and receives its heat from the hot gases leaving the fuel bed immediately below. The water is kept at a constant level by a float regulated valve, which is not shown in the illustration. A water overflow and an escape pipe, E, for the excess steam are provided. Coal is fired through a charging hopper, H, so designed that no air is allowed to enter with the

fuel and a magazine,N, is placed below this hopper so that the green fuel does not come in immediate contact with the fire. The gas outlet pipe, G, is furnished with valves so that the gas may be either admitted to the scrubbers or allowed to escape to the atmosphere through a waste pipe, O. Water seals, S, are provided on all producer connections so that explosions within the apparatus will do no damage. A coal storage bin of one car load capacity is at the north side of the producer room, as shown on the layout of the plant, Fig. 1, page 70. The coal is fed to the charging hoppers from a small bin above them, to which it is conveyed by a bucket conveyor driven by a small induction motor.

Scrubbers and Expansion Tanks:

The wet scrubber consists of a cylindrical steel shell containing a sprinkler near the top and layers of coke through which the ascending gases must pass. The gas enters at the bottom and leaves at the top. It then passes to the dry scrubber, filled with excelsior, where the particles of moisture are removed. The scrubbers are five feet and six inches in diameter, the wet scrubber being twelve feet high and the dry four feet high. From the dry scrubber the gas passes to a large expansion tank placed behind engine No. 1, from which this engine draws its supply. The functions of this tank are to reduce the velocity of the gas coming from the scrubber at the moment the admission valve opens; take care of the inertia of the moving gas at the closing of this valve, thereby regulating the fluctuations of draught on the producer to some extent; and provide a small storage space for fuel for the engine. When the second engine

was installed the gas main was continued from the end of this tank to the tank for the small engine and, in consequence, the receiver behind the large engine is not large enough for both and the two engines will not operate satisfactorily at the same time.

Engines:

The Muenzel engine is shown in cross section in Fig. 6, page 75. The engine is of the horizontal, single-acting, four-stroke cycle type and is built in single and twin engines. The air supply is admitted through the engine frame and the amount is regulated by a butterfly valve controlled by hand. Gas is admitted from the expansion tank through a hand controlled valve and mixed with the air by a specially designed nozzle. The amount of mixture entering the cylinder is controlled by a butterfly valve operated by the governor. Current for electric make-and-break ingition is supplied by a Bosch magneto mounted upon the cylinder head. The construction of this engine is well shown by the drawing referred to above. The frame and cylinder barrel, A, is cast in one piece and the cylinder bushing, B, is forced into the barrel from the head end. The cylinder head, H, contains inlet and exhaust valves, I and E, in the top and bottom, respectively, and is attached by means of stud bolts to the cylinder barrel. The crank swings between bearings in both sides of the frame and the flywheel is hung outside the frame, the end of the shaft being supported by a pedestal bearing in the single engines and by the opposite frame in the twin engines. Valve mechanisms and ignition apparatus, J, are driven from a layshaft carried in bearings on the outside of the engine frame and driv-

en, in turn, from the crank shaft by spiral reduction gearing.

Auxiliaries:

Compressed air for starting the engines is furnished by a small two-cylinder, single-stage, vertical, single-acting air compressor and a storage tank located in the producer room. This compressor is ordinarily driven by a small induction motor, but provision is made for driving it with a gascline engine when the plant is shut down. A small fan for blowing up the producer fires is found near this machinery so that it may be driven by the same power. The location of this machinery in the producer room where the air is full of ashes and coal dust makes it difficult to keep clean and in good condition.

Electrical Apparatus:

The generators are Westinghouse three-phase alternating current machines with exciters belted to the ends of the shafts. Current is generated at 2300 volts and stepped down for use. Switchboard connections and instruments are of standard Westinghouse types and the present arrangement is very inadequate in that only one unit can be operated at a time. The switchboard connections are shown in Fig. 7 , page 76. A motor generator set is used to supply a small amount of direct current at 500 volts for motor use. This is a very unsatisfactory arrangement for the following reasons: first, the motor generator set is not properly balanced, as it consists of a thirty horsepower motor and a fifty kilowatt generator; second, it cannot be operated at an economical load; third, on account of inadequate starting apparatus it cannot be stopped during periods when there is no demand for direct current; and fourth,

the induction motor lowers the power factor undesireably.

METHOD OF ATTACKING THE PROBLEM.

From the foregoing description of the present plant it is seen that a new building, new foundation under the 280-horsepower engine, better arrangement of apparatus within the building, and new wiring upon the switchboard are needed badly. Also, the sizes of the various units can be selected to care for the load expected in the future to better advantage. These reasons, coupled with the fact that the company has recently purchased property located more desireably for the erection of a gas plant, caused the decision to move the power plant into a new building upon this property.

In the solution of the problem of this design, the authors have deemed it advisable to conduct a short series of tests upon the gas engine installation for the purpose of determining the cost of producing power and the general conditions of operation of the plant in order to justify the selection of gas engine driven units for the new power house and suggest ideas for their most advantageous arrangement. The results of these tests and the permanent records of the company afforded data from which the probable load curve of the future was determined. The units were then selected to carry this probable load most advantageously, proper consideration being given to the present equipment and the provision of reserve units, and these units were then installed in a suitable building.

Estimates upon the probable cost of this plant were based upon data secured from various authorities.

THE TESTS.

OBJECTS:- The primary objects of these tests were as follows:-

1. To obtain the fuel consumption of the entire installation in pounds of coal per kilowatt-hour at the switchboard.

2. To obtain the entire cost of power production in cents per kilowatt-hour at the switchboard.

3. To observe the general conditions of operation of the gas engine driven electric power station.

Other objects of less importance in view were:-

4. The determination of the thermal efficiency of the plant (Ratio of heat equivalent of power output of plant at switchboard to heat supplied to producers in fuel).

5. Average volumetric analysis of gas leaving producers.

6. Average calorific value of gas leaving producers.

7. Coefficients or constants of performance of such apparatus as could be determined from the data taken without interfering with the operation of the plant.

METHODS OF CONDUCTING TESTS:- Three separate tests of twenty-four hours duration, each, were conducted upon the plant. Since it was desired to have the plant operating under the maximum load conditions of the year during the tests, they were run during the Christmas Holidays. The first test was

started Wednesday afternoon, December 22, 1909; the second, Friday afternoon, December 24, 1909; and the third, Sunday afternoon, December 26, 1909.

The tests were started and stopped by the alternate method adopted by the American Society of Mechanical Engineers in their test code for steam boilers. The fires are usually cleaned in the afternoon about three or four o'clock and the tests were started as soon after that as possible. The fires were cleaned as thoroughly as possible and sliced from the top, the grates shaken, the ashpits cleaned, and the producers filled with coal before the tests were started. This proceedure was repeated before the tests were stopped, careful attention being given to the weighing of the coal used during the tests and the ash and refuse that was taken from the ashpits upon the completion of the tests. In this manner it was thus practicable to conduct the tests without interfering in any way with the usual routine followed in the operation of the plant.

READINGS TAKEN:- The following readings were taken at intervals as shown upon the data sheets, pages 80, 81, and 82.

Temperatures:-

Outside air

Producer room

Engine room

Ashpit No.1 producer

" No.2 "

Gas leaving No.1 producer

Gas leaving No.2 producer

" " dry scrubber

Water entering wet scrubber

" leaving " "

" entering engine jackets

" leaving " "

Suction Pressures:-

Gas leaving No.1 producer

" " No.2 "

" " wet scrubber

" " dry "

Miscellaneous Readings:-

Weight and sample of coal fired

" " " " ash and refuse

Meter reading of amount of water used in scrubber

" " " " " " " " engine jackets

Speed of engines

Calorific value of gas produced by Junker Calorimeter

Sample of gas produced for volumetric analysis

Indicator diagrams from engines

Barometer

Electrical Readings:-

Kilowatts No.1 wattmeter

" No.2 "

Voltage

Current in line No.1

Current in line No.2

" " " No.3

Kilowatt-hours output

APPARATUS USED:- All apparatus used in the tests was carefully calibrated. These calibrations were only used in cases where great accuracy was desired, such as the weighing of the coal and the measuring of the electrical output, and other cases where corrections were relatively large.

Temperatures:-

All readings of temperatures were taken with Farenheit thermometers of suitable ranges. These thermometers were placed in brass thermometer cups filled with oil which were inserted in the proper places in the pipe lines. The thermometers used in obtaining the temperatures of the ashpits of the producers and that of the gas leaving the producers were inserted in these places through specially constructed stuffing boxes which allowed the bare bulbs of the thermometers to come in contact with the gases.

Suction Pressures:-

A water column was so constructed that the suction pressure at the various points could be secured by the proper manipulation of valves. Suction pressures were read in inches of water.

Weight of Coal and Ash:-

A staging was built on the tops of the two producers and an ordinary platform scale was placed upon it. The platform scale was calibrated by the use of weights that were weighed by

a carefully calibrated spring balance carried from the University laboratories. A box that would hold about six hundred pounds of coal was placed upon this scale in which the coal was weighed preparatory to firing. The coal was weighed in as large lots as possible to eliminate errors in the weighing. Samples of coal and ash were taken and quartered in the usual manner and preserved in air-tight jars for analysis at the University. The ashes and refuse were removed from the ashpits at the end of each test, weighed and sampled.

Measurement of Water:-

The scrubber water was measured by two three-quarter inch meters placed in multiple in the supply pipe, it being impossible to obtain a meter of the proper size. The jacket water was measured by a two inch meter placed in the pipe line near the first engine. These meters were calibrated in the University laboratories before being placed and their readings were taken as the true value, there being no means of collecting and weighing the water. The vaporizer water was disregarded, as the amount was small in comparison with the total amount used.

Speed of Engines:-

The explosions of the engines were counted by continuous counters which were connected to the exhaust valve levers and recorded the number of times these valves opened, or one-half the number of revolutions of the engine.

Calorific Value of Gas:-

The calorific value of the gas was obtained by the use of a Junker calorimeter, operating continuously, the sample for the same being taken from the gas main between the wet and dry scrub-

bers. As a continuous sample was required, an aspirator was connected to the sampling tube in such a way that a small stream of water flowing through the aspirator would draw the gas from the main, the gas and water flowing into a chamber in which a constant water level was maintained by throttling the outlet. Here the gas separated from the water and sufficient pressure was created by throttling the water outlet to force the gas through the apparatus. A head of ten feet, or thereabouts, was all that could be obtained on the aspirator, without considerable extra piping. Hence this head was used and found to be sufficient to operate the apparatus successfully, though slowly. A pressure of about two-tenths inches of water was maintained upon the gas at the meter.

Gas Samples for Analysis:-

The gas samples for analysis were also taken from the main between the wet and dry scrubbers. These samples were collected over saturated water in tin tubes provided for that purpose, these tubes being connected to the sampling tube by means of rubber tubing. In order to seal the samples the rubber nipples were bent double and wound with fine wire. However, upon analysis, they all showed considerable leakage and consequently this portion of the test was unsuccessful.

Indicator Diagrams:-

Indicators were attached to the cylinders of the engines, the reducing motions for their use being obtained from the manufacturers of the engines, the Minneapolis Steel and Machinery Company, of Minneapolis, Minnesota. This reducing mechanism consists of a horizontal piece attached to the cross-

head,parallel to the center line of the cylinder,carrying a slot which is inclined to the horizontal. A roller at the extremity of a short crank rolls in this slot and imparts an angular motion to a short shaft resting in bearings upon the frame of the engine. This shaft carries a lever to which the indicator cord is attached.

Electrical Measurements:-

The electrical output was measured by the two wattmeter method. The current coils of the two instruments were connected in two of the mains and the pressure coil of each instrument between the third line and the line in which the current coil of that meter was connected. The generator leads were opened at the generators (They could not be reached at the switchboard owing to the arrangement of wiring upon the back of the board) and knife switches inserted so that the instruments could be removed without interrupting the service. The pressure coils were connected to the line through a twenty-to-one potential transformer - a precision instrument - which was made to serve for both meters by the aid of two double-pole, double-throw knife switches. A voltmeter was placed across the low tension side of this transformer so that the voltage across two of the phases was read at the time the load was taken.

The switchboard instruments were calibrated by the "Comparison with a Standard" method, the standard in each case being a portable instrument which had been carefully calibrated at the University laboratories. The integrating wattmeters were carefully checked with the indicating wattmeters and then used to measure the total power output.

During the hours when the load was changing readings were taken every five minutes and at all other times at intervals of fifteen minutes. From these readings load curves were plotted which were integrated for total output, giving a check upon the integrating wattmeters. Only the readings taken at thirty-minute intervals are shown upon the data sheets, pages 80, 81 and 82.

Efficiency tests were not made upon the generators due to the fact that this could not have been done without incurring great risk of interrupting the service.

DATA:- All data taken during the tests is recorded on the data sheets, pages 80, 81 and 82. This data has been summarized in Table 1, "Summary of Data and Results of Tests", pages 42 to 49, and the "Sample Calculations", pages 50 to 55 , explain fully the methods used to obtain these results.

Temperatures of Producers:-

Considerable variation in the temperatures of the ashpits of the producers will be noticed throughout the tests and this is due to the fact that the fires do not remain at constant height above the grates. The variation in the temperature of the gas leaving the producer also depends upon the condition of the fires and the amount of steam that is being used. With a light load upon the producers, as in the last test, the temperature of the gas would naturally be expected to be low and these variations are therefore easily explained.

Calorific Value of Gas:-

The heating value of the gas would be expected to

vary considerably due to the method of handling the fires in this plant. Experience has taught that the fires should be disturbed as little as possible and for this reason the fires are only cleaned once and sliced from the top three times and the producers filled with coal three times, per day. By properly manipulating the steam supply the temperature of the fires is kept low so that clinkering does not become troublesome. It would be expected that variations in the quality of gas produced would be very gradual and the tests have verified this with regard to the calorific value of the gas. During the first test the gas was very poor, a mixture of about two parts air to one part gas being used at the engine, and this was due to poor fires and the presence of some clinker. During the second test, which was started twenty-four hours after the close of the first, the fires were in much better condition and the calorific value of the gas was much higher. During this test a mixture of seven to one was used at one time, which is probably as large a ratio as is ever used with producer gas, showing that the quality of the gas was very good. During the third test the gas was poor again, due to the stop on Sunday, which allowed the fires to settle and cool, thus cutting off the supply of steam, and the fact that the load was not heavy enough to pull the fires into good condition and produce sufficient steam to enrich the gas.

Coal:-

A slightly different coal was used during the last test which was unloaded Saturday and reached the producers on Sunday. The coal used is commercially known as "Number Two Nut" and is a very clean anthracite coal made up of a mixture

of small size nut and pea coals. It would be expected that considerably less coal would be fired during the last test, with its light load, than during the second test. This seeming inconsistency in the data is explained by the fact that the fires cannot be cleaned with the same degree of thoroughness from day to day and it may so happen that some ash and clinker were removed from the fires at the close of the last test that were not formed during the test, but were present at the start.

RESULTS.

Heat Balances:-

The "Heat Balances", Table 2, page 56, show the distribution of the various heat losses in the different tests. The first two tests check very nicely, but the third does not correspond to these values and this is probably due to the fact stated previously regarding the cleaning of the fires. The unaccounted for losses increase considerably in this test and this means a decrease in the percentages of the other losses.

Plant Economies:-

The results of greatest importance in these tests are tabulated in Table 3, page 57, as "Plant Economies". The coal consumption per kilowatt-hour compares very favorably with that given by the permanent records of the company as shown in Table 4, page 58, and is far below the best performance of the ordinary steam engine driven plant of this capacity. The fuel costs per kilowatt-hour cannot be compared with those given in Table 4, because the latter are actual values at the prevailing

prices of coal, which vary considerably.

The total water used per kilowatt-hour as given in Item 10, Table 3, is misleading. In this plant the jacket water is piped from the engine jackets into a well or cistern from which it is pumped into a tank upon the roof of the coal bin by a centrifugal pump and then used over again. In this way, only the evaporation must be supplied. The scrubber water is piped into the sewer because it is too dirty to be used again. The water for the vaporizers, which is a very small amount in comparison with the items mentioned above, must also be supplied. It is probable, then, that 1.25 cubic feet per kilowatt-hour will supply the requirements of the entire plant.

Cost of Power Production:-

The total cost of operation of a gas engine driven power plant consists of the following items:-

1. Fixed charges:-
    (a) Interest
    (b) Depreciation
    (c) Insurance and taxes
2. Maintenance and repairs
3. Lubricating oil and waste
4. Fuel cost
5. Cost of cooling water
6. Attendance

In order to determine the fixed charges it will be necessary to know the first cost of the plant. This is estimated as given in Table 5, page 59. The cost of producers was taken from curves in an article, "The Approximate Cost of Gas Power",

by M. P. Cleghorn, in "Power and the Engineer", March 31, 1908. The cost of the gas engines was estimated from data given in Carpenter and Diederichs' "Internal Combustion Engines". The cost of the 280-horsepower engine was assumed to be thirty dollars per horsepower and the 100-horsepower engine, thirty-six dollars per horsepower, erected. Cost of generators was obtained by the use of the well known formula:-

$$\text{Cost} = 9.0 \text{ kw.} + \frac{400{,}000}{\text{R.P.M.}},$$

which includes the cost of the exciters. The cost of the switchboard was estimated by roughly comparing it with switchboards of which the cost was known. The cost of the motor-generator set was obtained by the use of the formulas:-

Induction motor,

$$\text{Net cost} = \frac{530}{(\text{R.P.M.})^{0.3}} \sqrt{\text{H.P.}}$$

Direct current, direct connected generator,

$$\text{Net cost} = 12 \text{ kw.} + \$280$$

The cost of the belts was assumed to be $1.65 per square foot. The cost of the building was roughly fixed at $2,000, it being in very poor condition, as stated previously. The cost of auxiliaries and piping was estimated at ten percent of the total first cost. Carpenter and Diederichs give five percent for this value not including air compressors and similar machinery. As this plant contains a small air compressor, coal conveyor and gasoline engine, it was thought that ten percent would cover this cost.

Knowing the initial cost of the plant, the fixed

charges can now be estimated. The values given in Table 6, page 60, were taken from Carpenter and Diederichs' "Internal Combustion Engines". The cost of maintenance and repairs is taken as two percent of the original cost - a figure somewhat lower than that given by Carpenter and Diederichs - because no money was spent upon the building and very few repairs were made during the past year. The oil and waste cost is very low as the oil is filtered and used over again and this has been disregarded. The fuel cost was determined from the records of the company shown in Table 4, page 58, by calculating the fuel consumption for the entire year of 1909. It is evident that it would be incorrect to use the values determined by the tests, for the tests do not include standby losses. The cost of water used was assumed as three cents per thousand gallons, as it was pumped from deep wells owned by the company. The cost of attendance was obtained from the records of the company.

Conditions of Operation:-

The service during the ten days the authors spent in the plant was good in all respects, there being no interruptions, and it is safe to assume that this will continue when the engines have been put into better condition as regards foundations and bearings.

The attendance required by the gas engines and producers is considerably less than that required by steam engines and boilers of the same capacity, due to the comparatively small amount of fuel and ashes that must be handled. Double the present capacity of the plant could undoubtedly be handled by the force now employed, which consists of a day and a night engineer and one

fireman.

The producers have been found to operate most satisfactorily when not loaded heavily. This is due to the fact that the temperatures within the fire bed are not high enough to produce clinkering, which necessitates slicing and disturbing the fire.

Indicator diagrams taken from the engines are shown on pages 86 and 87. These diagrams are representative of present practice in gas engine operation. Pump diagrams taken with a ten pound spring are shown on page 88 . One of these diagrams - that of the left hand side of engine No. 1 - shows that the exhaust valve closes early, but the others show proper adjustment.

Overall Thermal Efficiency of Plant:-

The overall thermal efficiency of the plant, from the coal pile to the switchboard, as shown in Table 3, page 57, is excellent when compared with similar values obtained from steam engine driven plants of similar character, which seldom are above six or eight percent.

Calorific Value of Gas:-

The heating value of the gas produced in this plant is about the same as that given by various authorities on the subject. Carpenter and Diederichs say that gas made from anthracite coal should have a heating value of 145 British thermal units per cubic foot, but this is somewhat higher than was obtained by Messrs. Garland and Kratz in their tests in the Mechanical Engineering Laboratory of the University of Illinois. In their article in the December, 1909, number of the "Journal of the American Society of Mechanical Engineers" they give an

average value of 138.1 British thermal units per cubic foot. The values obtained in the first and last tests are lower than these, but this was due to the poor condition of the fires, as explained previously. The quality of the gas during the second test was very good and compares very favorably with the preceeding statements.

Coefficients or Constants of Performance:-

By taking a ratio between electrical horsepower-hours output of the plant and the indicated horsepower-hours, it was possible to obtain an efficiency or constant of performance for the engines, belt transmission, and generators, including the electrical losses. This value was obtained for the various units, as shown in Table 1, pages 42 to 49. The highest value, 87.8 percent, was obtained during the last test when the 100-horsepower unit was used for twenty-four hours continuously. This unit was thus operated at much nearer its rated capacity than in the previous tests and a higher value of this ratio would be expected.

CONCLUSIONS.

The authors realize that tests of twenty-four hours duration are too short for apparatus of this character, where conditions cannot be maintained constant. Particularly does the great fluctuations of the fires, that may be expected from day to day, affect short tests. Nevertheless, the results of these tests show conclusively that the service is now good and that the present gas engine installation produces power cheaper than could

a steam engine plant of similar capacity. Adding to these the fact that the present equipment is nearly new and in such condition that it could not be discarded without great loss, the installation of gas engine equipment in the new plant is warranted.

THE DESIGN.

PROBABLE FUTURE LOAD CURVE:- The future load upon the plant depends upon the increase in the present load, and this demands a study of existing conditions. The present load was analysed and comparisons made with data from other plants serving cities of the same size. The growth of the plant since gas was installed was studied and proposed extensions were considered.

Present Load:-

Since the installation of the present plant, the daily output has materially increased, as shown by curves on Plate 1, page 63. This increase is seen to be approximately thirty percent by comparing any month in 1909 with the same month in 1908. These values give no key to the future load, however, since the records do not cover a sufficient period of time.

Several representative daily load curves are shown on Plates 2, 3 and 4, pages 64 , 65 , and 66 . The curve taken during the month of December, 1909, is the only one here considered and is used as a basis for the future curve because the peak load is greatest at this time of the year due to the over-lapping of the power and lighting loads.

Analysis of Present Load and Comparisons:-

Table 7, page 61, is taken from the "Electrical World", May, 1909, and contains central station data for small towns averaging about the size of Hoopeston. Taking this table as a guide, it would seem that only a very small increase in connected load could be expected, as there is at present a greater

connected load than in the average town of this size. The station capacity and transformer installation are both low which, combined with the greater connected load and higher load factor, would seem to indicate business activity on the part of the management. This table, however, cannot be taken as an absolute guide as it does not contain data from enough stations and nothing is known of the cities except that they are "average" Illinois and Iowa towns. Hoopeston is above the average city in that there is considerable manufacturing carried on and many large residences indicate considerable wealth.

In order to facilitate the discussion of the possibilities of increase in different kinds of load, the present load has been divided as follows, as is shown in Table 8, page 62:-

Lighting:-

1. Residence
2. General business
3. Office, shop, factory, etc.
4. Churches and halls
5. Street lighting
6. Emergency connections

Power

Future extensions.

Lighting Load:-

In making a comparison between Tables 7 and 8, it is seen that the connected lighting load is higher than the average. The large factory installations have but little effect upon this, as emergency connections were not included in making up the data for comparison. The principal factor is residence lighting. There

are still residence districts that are undeveloped, however, particularly those including the smaller cottages requiring five to twelve lights. This may be seen from the fact that there are only 271 residence connections with a total of 4500 lamps installed, or an average of sixteen lamps per installation. Another indication of this fact will be found in another column of Table 8, showing the number of residences connected per 100 population which, in comparison with the data given in Table 7, is very low. In making an estimate of the future residence lighting load it was assumed that four lights per residence would be burning on the peak load. This is high for the early peak in December and still higher for the summer months, but is a good average where the maximum load is considered as the hour from lighting until retiring.

The second class of lighting load, general business lighting, is all peak load as it is made up of window illumination, public library and club room lighting, etc. During the period of unsatisfactory service in the past practically all of the merchants installed gasoline lighting systems and are still using them for store lighting, although electric service is employed in most cases for windows. This may be due to the attitude of the company as they do not seem to desire to cater to this class of service, it being peak load business. The new installation, which will provide reserve units on the peak load, will warrant securing this business.

Factory, office and shop lighting is rather hard to estimate. Closing, as they do, at five or six o'clock, the lights may seldom be turned on and yet, on a dark or cloudy day, every

such building may have all of its lights on. This is unusual, however, and allowance is made for about one-half.

Churches and halls are not usually lighted until late in the evening and when they are on residence lights are off to some extent. This class of lighting is not considered as adding to the peak load.

Street lighting is a peak load. At present, this is small in amount, but a new contract has been practically decided upon which will give a load of sixteen kilowatts.

There are several emergency connections to factories having their own power plants, but this load is unusual and need not be allowed for, as the reserve unit will care for it when occasion demands.

Power:-

The power field has been quite thoroughly canvassed, resulting in a fair day load. While the electric motor has driven out the gasoline engine in most cases, there is still much steam power used. In fact, the electric power used is but a small fraction of the total power used in the city. There is about 750 horsepower of steam engines installed in various factories in the city - not including the city pumping station, which is nearly new - and the smallest installation is of eighty horsepower capacity. The canning factories,which are in operation only six or eight weeks of the year, have 200 horsepower installed. Of the remaining 550 horsepower, two factories with a total of 280 horsepower have recently put in new steam equipment and, for the present, not much change in the power situation can be looked for.

Future Extensions:-

Arrangements are practically completed for the build-

ing of a transmission line to Rossville, a town of about 1200 inhabitants, located six miles south of Hoopeston, and taking over the plant and service at that place. As no data concerning Rossville was at hand, the present and future load conditions at that place were taken as supplied by the Hoopeston Gas and Electric Company.

The probable future load curve as determined after carefully studying the above items is shown on Plate 5, page 67, and from this curve the choice of units was made.

SELECTION OF UNITS:- In making a choice of units for the new plant, we are confined within rather narrow limits. The present installation, with the exception of the 85-kilowatt generator, has been in service less than two years and cannot be discarded for it is giving good results, as shown by the tests and the records of the company. This installation, as before stated, consists of a 280-horsepower twin engine and a 100-horsepower single engine belted to 200- and 85-kilowatt alternators, respectively. The present combination of a 100-horsepower engine driving an 85-kilowatt generator is not desireable,as full load on the engine is considerably less than full load on the generator and, furthermore, the generator will carry forty to fifty percent overload, while the gas engine will only carry about ten percent more than its rated capacity.

With these ideas in mind the following combinations of units were carefully considered:-

Case (a):-

Unit No. 1 - 200 kilowatts

Unit	No.	2	-	85	kilowatts
"	"	3	-	125	"
"	"	4	-	35	"

Case (b):-

Unit	No.	1	-	200	kilowatts
"	"	2	-	125	"
"	"	3	-	85	"
"	"	4	-	35	"

Case (c):-

Unit	No.	1	-	200	kilowatts
"	"	2	-	125	"
"	"	3	-	85	"

In Case (a), units number 1 and 2 are the present equipment of the plant and numbers 3 and 4 will be new, number 3 being a twin engine and number 4 a single engine.

In Case (b), unit number 1 is taken from the present installation. Number 2 will consist of a new generator and a twin engine, one side of which is obtained from the present installation and the other side is new. Number 3 will consist of a generator from the present plant and a new 140-horsepower twin engine. Number 4 will be the same as in Case (a).

In Case (c), the units will be the same as in Case (b) except that the 35-kilowatt unit will not be installed.

From the load curve, Plate 5, page 67, it is seen that a 35-kilowatt unit would carry the load from three to five hours each night and also on Sundays and other days when power was not being used to any great extent. It could also be used to advantage to help other units out when they are loaded heavily.

Figuring interest and deprecaition at fourteen percent, 500 pounds of coal per day, or about one-fifth of the present consumption, would have to be saved to make it a paying proposition. This saving would be impossible, as is shown by the tests and the company's records of operation. Also, there is a possibility that the Malleable Iron Works will put on a night shift in the near future, as their present equipment is being forced to the limit and they are rapidly falling behind in their orders, and this will mean a load of sixty kilowatts from midnight until six in the morning. Considering these facts, the 35-kilowatt unit drops out of consideration, leaving Case (a) - minus unit number 4 - and Case (c) to be considered.

A twin engine is desired instead of a single engine, whenever possible, because pulsations in speed will be reduced and this will aid the operation of the generators in parallel. Also, by using the present single engine as one side of a twin engine and securing another 140-horsepower engine for the 85-kilowatt generator, the capacity of the plant will be increased forty horsepower over that given in Case (a), which is desired, and the generator will be able to carry a load nearer its rating. For these reasons, Case (c) seems the most logical combination of units for the new plant.

Producer Room Installation:-

Gas producers can be operated through long periods of time without shutdowns for cleaning and repairs. The present installation consists of two producers rated at 150-horsepower each and one set of scrubbers, as stated previously. The maximum load shown on the probable future load curve, Plate 5, page 67,

is approximately 250 kilowatts and this means that units one and three will be in operation, giving a total capacity of 420 horsepower. By adding one more 150-horsepower producer to the present equipment it will be possible to handle this load and, if future conditions demand, another can be added making a second set similar to that at present in operation. Another wet scrubber will be installed for this producer and both wet scrubbers will be connected to the present dry scrubber. By proper arrangement of valves it will be possible to operate any producer and either wet scrubber. The dry scrubber can be operated continuously without interruption and therefore a by-pass is not needed.

LAYOUT OF POWER PLANT:- The proposed layout of the future plant is shown in Figure 2, page 71. As shown by the elevations, the producer room floor is three feet lower than the floor of the engine room, this giving room over the producers for slicing and for the location of a small coal bin of about two tons capacity. Coal storage space is provided as shown and the coal will be carried to the bin above the producers by a small bucket conveyor. The piping in the producer room will be laid in a trench in the concrete floor. No auxiliary machinery will be located in the producer room on account of the ashes and dust.

The engine room will contain the main generating units arranged as shown, with the head ends of the engine cylinders toward the producer room. The piping will be carried in a small basement extending from the engine foundations to the wall of the producer room, which will give accessibility for repairs. Each engine will have an individual expansion tank and a separate

gas line from a short header at the dry scrubber. Cooling water will be run through the jackets by gravity and will drain into a cistern below the floor of the oil room from which it will be pumped into a tank upon the roof to be cooled and used over again. The water supply will consist of a deep well and a connection with the city main. As in the present plant, all engines will be belt connected to their respective generators and the exciters will be belted to the ends of the generator shafts. The location of the switchboard is unfortunate, but could not be improved upon. Had it been placed at the head ends of the engines, it would have interfered with the piping and if placed at the side of the room, it would have been as inaccessible as in the location chosen.

The southwest corner of the building is devoted to a shop and toilet room. The auxiliary machinery, consisting of a gasoline engine, air compressor, fan and air storage tanks will be placed in this room. A basement having its floor on a level with the floor of the piping tunnel beneath the cylinder-heads of the engines, will be located beneath this part of the building and will serve for an oil room in which the filters will be located and oil will be stored. The jacket water cistern will located in one corner of this room, the centrifugal pump used to elevate the water to the tank on the roof being placed in the shop above. A second story will be provided for the storage of such supplies as are found about a power plant. A stairway will connect the different floors of this portion of the building and materials can be moved into either floor readily by the use of a block and tackle hoist outside of the build-

ing, doors on each floor and a movable grating opening into a sub-basement being provided.

The engine room will be constructed with brick walls and a flat roof supported with suitable trusses carried on the walls. The producer room will be somewhat higher than the engine room, as shown, and will be covered by a gabled roof. The portion of the building devoted to the shop and store room will be constructed with heavy brick walls and reinforced concrete floors and roof. The flat roof will provide a tank for the jacket water.

Switchboard:-

A front elevation and a diagram of connections of the present switchboard, which is of the standard Westinghouse type, are shown in Figures8 and 7, pages 76 and 77 . The board consists of five panels as follows: two generator panels, one exciter panel, one feeder panel and a motor-generator set panel. Each generator panel has three ammeters, one integrating wattmeter, one three-pole single-throw oil switch, main fuses, generator and exciter field rheostats, generator field plugs, voltmeter plugs, and a voltmeter which is mounted upon a swinging bracket at the end of the board. Upon the exciter panel is an ammeter for each generator field and a frequency meter. The auto-starter for the motor-generator set, and also the direct current circuit breaker are mounted upon this panel. Upon the motor-generator panel is a direct current ammeter, integrating wattmeter, field rheostat and switch. There are four alternating current feeder circuits each controlled by a three-pole single throw oil switch mounted upon the feeder panel.

The board is new and will be used in the new plant.

The arrangement of the instruments is good but the wiring is poorly arranged and is in poor condition. At the time of our tests it was practically impossible to get at any of the connections on the rear of the board owing to the arrangement of the instrument transformers, rheostats, etc. This feature can be greatly improved upon.

The new board is shown in Figures 10and 9, pages 79 and 78. Some changes and improvements will be made and three new panels added. Two sets of buses will be installed as parallel operation is somewhat doubtful with the present equipment. The four-cycle twin engines which will be installed will run at slightly different speeds and hunting may be excessive. Also, it may be desireable at times to operate the Rossville circuit separately. There will be three generator panels with the same arrangement as at present except that an indicating wattmeter will be connected to each machine, and the integrating wattmeters will measure the output of the buses instead of each machine. The present oil switches will be replaced by double-throw switches. Circuit breakers are not provided for the generators since a momentary rush of current is not so disastrous with an alternator as with a direct current machine. The breakers would be liable to open when the machines are being synchronised and they may open while running and cause a shutdown until the machines can be paralleled again, and so fuses are relied upon to protect the generators.

The exciters will be operated in parallel, the voltage being regulated by a Tirrill regulator. Ammeters are provided for each exciter and are also placed in each generator field.

The single-throw oil switches in the feeder circuits will be replaced by double-throw oil circuit breaker.

A separate circuit will be installed for Rossville. This will have three ammeters, an integrating wattmeter, voltage regulator and compensated voltmeter and a three-pole, double-throw oil circuit breaker.

CIRCUITS:- The voltage in different parts of the city is low, due in some cases to overloaded transformers, perhaps, but principally to small conductors and improper distribution. A map of the city showing the present lines and a proposed layout of the new lines is shown on page 68.

Pole Line:-

It has not been the intention of the writers to give any specifications but merely suggestions as to the location of lines and transformers. The present lines are badly run down, a great many of the poles being unfit for use although most of the wire is practically new. Some extensions will have to be made, some line rebuilt and some removed, but part has been allowed to stand, notably the line leading to the foundry. In rebuilding and changing the lines they have been placed in the alleys so far as possible. Thirty-foot poles are recommended in most cases, but in the business district higher poles have been used. In selecting the poles provision was made for the line going to Rossville, which will follow down Market Street and over to Second Avenue and then south to Rossville, this route being chosen because there is at present one installation one mile south of town upon this road.

No wire smaller than number ten is recommended for line

use but there is already so much number twelve on the lines that it has been decided to use some of it over but only on short extensions to the primaries.

The transformers are placed as near the centers of distribution as possible and long secondaries are avoided. Three wire secondaries are used in most cases so as to cut down the copper loss. In calculating the size of copper six percent drop is assumed - two percent primary, two percent in the transformer and two percent in secondary.

Calculations:-

Sample calculations for the three-phase line to the foundry located 4,850 feet from the plant are as follows:-

Assume maximum condition of load, which will be seventy kilowatts(Balanced) consisting of fifty-five kilowatts of power load and fifteen kilowatts of lighting load. Assume power factor as eighty percent, since this is a power load, and assume five percent drop to the transformer.

Then: $$P = \sqrt{3}\ E\ I\ \cos\theta$$

or, $$70,000 = \sqrt{3} \times 2300 \times I \times 0.80$$

From which, $$I = \frac{70,000}{\sqrt{3} \times 2300 \times 0.80} = 22 \text{ amperes per line.}$$

$$\text{Volts to neutral} = \frac{2300}{\sqrt{3}} = 1330$$

and $$0.05 \times 1330 = 67 \text{ volts.}$$

Neglecting inductance and capacity,

$$\text{Volts drop} = R\ I$$

From which, $$R = \frac{E}{I} = \frac{67}{22} = 3+ \text{ ohms.}$$

Distance = 4,850 feet, and 2 x 4,850 = 9700 feet.

$\frac{9700}{3}$ = 3233 feet per ohm and this corresponds to

number four wire, which is already in place.

Street Lighting:-

Perhaps nothing on the system is in worse condition than the street lighting circuit. This at present consists of five multiple arc lamps and 126 carbon lamps operated from transformers at different points over the line. The circuit is constructed entirely of old material and zig-zags back and forth across the streets in order to avoid the trees. Most of the lamps are suspended from pieces of boards nailed to the poles and are without reflectors. Nine series tungsten lamps have recently been installed for demonstration purposes and the city is considering a new contract specifying series tungstens for the residence districts and arc lamps in the business part of town.

The proposed layout includes twenty 6.6-ampere series arc lamps and 150 40-watt, 6.6-ampere series tungsten lamps all operated on one circuit. The arc and incandescent circuits are made separate and are put in series by a plug switch at the plant so that either circuit can be burned without the other and in case the arc circuit opens it can be cut out without putting the entire city in darkness. A sixteen-kilowatt Westinghouse constant current transformer is used to operate the system.

The arcs will be suspended over the street centers, Cutter suspension pulleys being used. The incandescent lamps are to be used in connection with the Westinghouse street hood, complete with reflector, bracket and lamp guard. These automatically short circuit a lamp in case it burns out and this preserves the continuity of the circuit.

OTHER APPARATUS:- A motor-generator set is at present installed

in the plant to give 500- volt direct current. The motor is a 30-horsepower, three-phase, 2200-volt machine and the generator is a fifty-six-kilowatt, 500-volt direct current machine. The combination is unbalanced yet they are direct-connected and mounted on the same bed-plate. This set has a connected load of 125 horsepower and runs at practically no load from five o'clock in the morning until one at night, the output averaging only about sixty kilowatt-hours daily. The largest motor is a fifty-horsepower compound wound machine running a passenger elevator in a four-story building. When the elevator starts it draws about sixty-five amperes and causes a fluctuation in the alternating current voltage. It would seem that the elevator is not well balanced and has a great deal of unnecessary friction to require such a large motor and the best remedy for such a condition would be to overhaul the elevator. No change is made in the motor-generator set for the time being as power conditions will not warrant it but it is recommended that the 500-volt power be developed so the set can be run at better efficiency.

This induction motor running light lowers the power factor of the system considerably and is very undesireable for this reason. To counteract this a synchronous motor is recommended to be placed on the deep well pump. The pump operates but a short time each day and so the motor could be used as a rotary condenser and thus raise the power factor.

PRINCIPAL DIMENSIONS OF ENGINES.

	Number 1	Number 2
Type of engine	Four-stroke cycle	
Number of cylinders	2	1
Arrangement of cylinders	Horizontal, twin	Horizontal
Fuel used	Producer gas	
Compression, lbs. per sq.in.	140	180
Bore of cylinders, inches	21.75	18.75
Length of stroke, inches	32	27
Rated speed, R. P. M.	175	190
Rated capacity, horsepower	280	100
Ignition	High tension make-and-break, Bosch Magneto	
Diameter of flywheel, feet	9	9
Weight of flywheel, pounds	34,000	20,000

TABLE NO. 1.

SUMMARY OF DATA AND RESULTS OF TESTS.

Item No.	Test No. 1	Test No. 2	Test No. 3
1. Duration of test, hrs.	24	24	24
2. Av. producer room temp., $^{\circ}F$	70.9	83.05	78.9
3. Av. outside temp., $^{\circ}F$	16.32	30.45	16.27
4. Av. ashpit temp., #1 producer, $^{\circ}F$	161.5	168.5	205.
5. " " " , #2 " , $^{\circ}F$	188.5	180.8	219.05
Average gas temperatures, $^{\circ}F$:-			
6. Leaving #1 producer	493.6	424.0	348.6
7. " #2 "	483.4	455.5	383.9
8. " dry scrubber	61.75	68.7	63.55
9. Total cu.ft. scrubber water used	1557.7	1138.6	1091.1
10. Scrubber water per hour, cu.ft.	64.8	47.4	45.4
11. Total weight of scrubber water, lb.	97,200	71,000	68,050
12. Weight of scrubber water per hour, lb.	4,040	2,960	2,835
13. Av. Temp. scrubber water inlet, $^{\circ}F$	51.46	52.41	50.3
14. " " " " outlet, $^{\circ}F$	71.1	71.7	61.5
15. " " rise in scrubber water, $^{\circ}F$	19.64	19.29	11.2

TABLE NO. 1. SUMMARY OF DATA AND RESULTS OF TESTS (Continued)

Item No.	Test #1	Test #2	Test #3
16. Total heat lost through scrubber water, B.t.u.	1,909,000	1,370,000	763,000
17. Total heat lost through scrubber water per hour, B.t.u.	79,400	57,150	31,760
Average suction pressures, inches water:-			
18. Number 1 producer outlet	0.41	0.335	0.295
19. " 2 " "	0.441	0.366	0.339
20. Wet scrubber outlet	2.765	2.1	1.855
21. Dry " "	3.34	2.495	2.87
22. Av. calorific value of gas by Junker calorimeter, B.t.u. per cu.ft.	117.0	140.67	120.94
23. Total weight coal fired, lb.	3,042	2,450.5	2,276
24. Av. weight coal fired per hour, lb.	126.7	102.	94.7
25. Proximate analysis of coal:-			
Fixed carbon, percent	73.32	71.64	79.60
Volatile matter, "	6.29	7.16	4.20
Moisture, "	1.93	1.69	1.80
Ash, "	18.46	19.51	14.40
	100.00	100.00	100.00

TABLE NO. 1. SUMMARY OF DATA AND RESULTS OF TESTS (Continued)

Item No.	Test #1	Test #2	Test #3
26. Ultimate analysis of coal:-			
Carbon (C) percent	78.66	-----	-----
Hydrogen (H) "	1.97	-----	-----
Oxygen (O) "	1.78	-----	-----
Nitrogen (N) (estimated) "	0.80	-----	-----
Sulphur (S) "	0.59	-----	-----
Ash "	14.40	-----	-----
Moisture (at 105 °C) "	1.80	-----	-----
	100.00		
Calorific value by analysis, B.t.u. per lb.	12,525		
27. Calorific value, B.t.u. per lb. of air dry coal, by oxygen calorimeter	11,726	11,496	12,359
28. Total heat supplied to producer, B.t.u	35,670,000	28,170,000	28,130,000
29. Heat supplied to producer per hr., "	1,486,000	1,173,000	1,172,000
30. Weight of ash and refuse, lb.	575	488	506
31. Analysis of ash and refuse:-			
Earthy matter, percent	86.65	81.56	86.82
Moisture, "	0.07	0.00	0.02

TABLE NO. 1. SUMMARY OF DATA AND RESULTS OF TESTS (Continued)

Item No.	Test #1	Test #2	Test #3
32. Minutes #1 engine was on	384 + 160 = 544	418	-----
33. Minutes #2 engine was on	896	1022	1440
34. Hours #1 engine was on	9.07	6.965	-----
35. Hours #2 engine was on	14.93	17.035	24.0
36. Av engine room temp., °F	69.07	70.9	65.4
37. Total revolutions #1 engine	67864+28204 = 96,068	73,474	-----
38. Total revolutions #2 engine			267,978
39. Av. speed #1 engine, R.P.M.	176.72;176.275		
Mean	176.6	175.78	-----
40. Av. speed #2 engine, R.P.M.	186.12	184.53	186.1
41. Av. explosions per min., #1 engine	88.36;88.137		
Mean	88.3	87.89	-----
42. Av. explosions per min., #2 engine	93.06	92.265	93.05
Mean effective pressures:-			
43. #1 engine, R.H.cylinder	44.3;30.4		
Mean	39.9	37.07	-----
44. #1 engine, L.H.cylinder	40.9	38.03	-----
45. #2 engine	48.78	32.16	36.02

TABLE NO. 1. SUMMARY OF DATA AND RESULTS OF TESTS (Continued)

Item No.	Test #1	Test #2	Test #3
46. Engine constant, #1 engine	.03005	.03005	.03005
47. " " , #2 "	.0188	.0188	.0188
48. Av. I.H.P., #1 engine, R.H.cylinder	117.6;80.4		
Mean	105.8	98.	-----
49. " " , #1 " , L.H.cylinder	108.5	100.5	-----
50. " " , #1 " , total	214.3	198.5	-----
51. " " , #2 " , "	85.4	55.8	63.0
52. Total I.H.P.hr. output, #1 engine	1943	1382	-----
53. " " " , #2 "	1276	950	1512
54. " " " , both engines	3219	2332	1512
55. Jacket water #1 engine, cu.ft.	687.15+223 = 910.15	882	-----
56. " " #2 " , "	652.6	680.4	1204.5
57. " " both " , "	1562.75	1562.4	1204.5
58. " " #1 " , cu.ft. per hr.	100.5	126.6	-----
59. " " #2 " , " " "	43.62	39.9	50.2
60. " " both " , " " "	65.2	65.15	50.2
61. " " #1 " , lbs.	56,793.36	55,036.5	-----

TABLE NO. 1. SUMMARY OF DATA AND RESULTS OF TESTS (Continued)

Item No.	Test #1	Test #2	Test#3
62. Jacket water #2 engine, lbs.	40,722.24	42,456.96	75,160.8
63. " " both " , "	97,515.6	97,493.76	75,160.8
64. Av. temp. jacket water inlet,#1 engine	51.87;51.67	53.11	-----
65. " " " " " ,#2 "	51.24	52.11	50.14
66. " " " " outlet,#1 "	116.23;115.83	109.5	-----
67. " " " " " ,#2 "	117.5	109.46	103.5
68. " " rise of jacket water, #1 "	64.36;64.16	56.39	-----
69. " " " " " " , #2 "	66.26	57.35	53.36
70. Heat lost through jacket water,#1 "	3,652,437.61	3,103,525.15	-----
71. " " " " " ,#2 "	2,698,255.62	2,434,906.66	4,010,580.29
72. " " " " " ,Total	6,350,693.23	5,538,431.81	4,010,580.29
73. " " " " " , B.t.u. per hour, both engines	264,500	230,600	167,000
74. Same, #1 engine	405,500	446,000	-----
75. " , #2 "	181,000	142,800	167,000
76. Total kw.hr. output, #1 unit	906	810	-----
77. " " " , #2 "	698	458	990
78. " " " , total	1604	1268	990

TABLE NO. 1. SUMMARY OF DATA AND RESULTS OF TESTS (Continued)

Item No.	Test #1	Test #2	Test #3
79. Average load on #1 unit, kw.	99.9	116.2	-----
80. " " " #2 " , "	46.7	26.9	41.25
81. " " " plant, "	66.8	52.85	41.25
82. E.H.P. equivalent of above, #1 unit	133.85	155.8	-----
83. " " " " , #2 "	62.6	36.07	55.3
84. " " " " , plant	89.5	70.85	55.3
85. Mechanical efficiency unit #1, percent	62.5	78.5	-----
86. " " " #2, percent	73.25	64.7	87.8
87. " " plant, percent	66.8	72.8	87.8
88. B.t.u. equivalent of average load	228,000	180,300	140,700
89. Thermal efficiency of plant, percent	15.34	15.36	12.00
90. Lb. coal used per kw.hr.	1.894	1.932	2.298
91. Cu.ft. scrubber water per kw.hr.	.971	.898	1.102
92. " jacket water per kw.hr.	.974	1.23	1.22
93. Total water used, cu.ft. per kw.hr.	1.945	2.128	2.322
94. Cost of coal per ton in bin, dollars	4.50	4.50	4.50
95. " " " " pound " " , cents	.225	.225	.225

TABLE NO. 1. SUMMARY OF DATA AND RESULTS OF TESTS (Continued)

Item No.	Test #1	Test #2	Test #3
96. Cost of coal per kw. hr., cents	.427	.435	.517
97. Labor cost per day, dollars	7.42	7.42	7.42
98. " " " kw.hr., cents	.462	.586	.75
99. Sum of fuel and labor costs, cents per kw.hr.	.889	1.021	1.26
100. Station load factor, percent	23.45	18.52	14.45

S A M P L E   C A L C U L A T I O N S

The following calculations are presented merely to explain the methods followed in computing the results of the tests as given in Table 1 immediately preceeding this page. In these computations abstract numbers will be employed as far as possible and the calculations are only to be used in connection with the preceeding table. Item numbers will be used in the formulas and all quantities substituted for the calculations will be taken from the first test, as far as is possible. Wherever necessary, explanations of the data will be given.

Item No.

9. As mentioned previously, two meters were used to measure the scrubber water, one of which read in cu.ft. and the other in gals. Therefore:

$$\text{Item No. 9} = \text{Cu.ft. indicated by meter \#1} + \frac{\text{gals. registered by meter \#2}}{7.48}$$

$$= (2845.7 - 2120) + \frac{6836 - 618}{7.48}$$

$$= 725.7 + 832 = 1557.7$$

10. $= \frac{\text{Item 9}}{\text{Item 1}} = \frac{1557.7}{24} = 64.8$

11. $= \text{Item 9} \times 62.4 = 1557.7 \times 62.4 = 97{,}200$

12. $= \text{Item 10} \times 62.4 = 64.8 \times 62.4 = 4{,}040$

15. $= \text{Item 14} - \text{Item 13} = 71.1 - 51.46 = 19.64$

Item No.

16. $= \text{Item 11} \times \text{Item 15} = 97{,}200 \times 19.64 = 1{,}909{,}000$

17. $= \text{Item 12} \times \text{Item 15} = 4{,}040 \times 19.64 = 79{,}400$

22. As the quantity of data secured in the operation of the Junker Calorimeter was very large it was thought adviseable to omit it from this report. The calculations were made in the usual manner and the values given are corrected for temperature and pressure.

24. $= \dfrac{\text{Item 23}}{\text{Item 1}} = \dfrac{3{,}042}{24} = 126.7$

25 to 27 were obtained from the chemist

28. $= \text{Item 23} \times \text{Item 27} = 3{,}042 \times 11{,}726 = 35{,}670{,}000$

29. $= \text{Item 24} \times \text{Item 27} = 126.7 \times 11{,}726 = 1{,}486{,}000$

34. $= \dfrac{\text{Item 32}}{60} = \dfrac{544}{60} = 9.07$

35. $= \dfrac{\text{Item 33}}{60} = \dfrac{896}{60} = 14.93$

37 and 38. Revolution counter was attached to exhaust valve lever, as stated before, therefore, Items 37 and 38

= 2 x revolution counter reading.

Considerable trouble was experienced with the counter on engine No. 2, and this was not remedied until the last test.

39. $= \dfrac{\text{Item 37}}{\text{Item 32}} = \dfrac{96{,}068}{544} = 176.6$

Item No.

40. $= \frac{\text{Item 38}}{\text{Item 33}} = \frac{67,978}{1,440} = 186.1$ (Test #3)

In Tests #1 and 2, trouble was encountered with sticking of the revolution counter. Average values of speed were taken from the data secured and assumed to apply throughout that test.

41. $= \frac{\text{Item 39}}{2} = \frac{176.6}{2} = 88.3$

42. $= \frac{\text{Item 40}}{2} = \frac{186.12}{2} = 93.06$

46. $= \frac{L\ A}{33,000} = \frac{32 \times 21.75^2 \times .7854}{12 \times 33,000} = 0.03005$

47. $= \frac{L\ A}{33,000} = \frac{27 \times 18.75^2 \times .7854}{12 \times 33,000} = 0.0188$

48. = Item 46 x Item 43 x Item 41

$= 0.03005 \times 39.9 \times 88.3 = 105.8$

49. = Item 46 x Item 44 x Item 41

$= 0.03005 \times 40.9 \times 88.3 = 108.5$

50. = Item 48 + Item 49 = 105.8 + 108.5 = 214.3

51. = Item 47 x Item 45 x Item 42

$= 0.0188 \times 48.78 \times 93.06 = 85.4$

52. = Item 50 x Item 34 = 214.3 x 9.07 = 1,943

53. = Item 51 x Item 35 = 85.4 x 14.93 = 1,276

54. = Item 52 + Item 53 = 1,943 + 1,276 = 3,219

57. = Item 55 + Item 56 = 910.15 + 652.6 = 1,562.75

58. $= \frac{\text{Item 55}}{\text{Item 34}} = \frac{652.6}{9.07} = 100.5$

Item No.

59. $= \frac{\text{Item } 56}{\text{Item } 35} = \frac{652.6}{14.93} = 43.62$

60. $= \frac{\text{Item } 57}{\text{Item } 1} = \frac{1562.75}{24} = 65.2$

61. = Item 55 x 62.4 = 910.15 x 62.4 = 56,793.36

62. = Item 56 x 62.4 = 652.6 x 62.4 = 40,722.24

63. = Item 61 + Item 62 = 56,793.36 + 40,722.24 = 97,515.6

68. = Item 66 - Item 64 = 116.23 - 51.87 = 64.36

69. = Item 67 - Item 65 = 117.5 - 51.24 = 66.26

70. = Item 61 x Item 68 = 42,798.16 x 64.36 = 2,759,638.38
13,915.2 x 64.16 = 892,799.23
3,652,437.61

71. = Item 62 x Item 69 = 40,722.24 x 66.26 = 2,698,255.62

72. = Item 70 + Item 71 = 3,652,437.61 + 2,698,255.62
= 6,350,693.23

73. $= \frac{\text{Item } 72}{\text{Item } 1} = \frac{6,350,693.23}{24} = 264,500$

74. $= \frac{\text{Item } 70}{\text{Item } 34} = \frac{3,652,437.61}{9.07} = 403,500$

75. $= \frac{\text{Item } 71}{\text{Item } 35} = \frac{2,698,255.62}{14.93} = 181,000$

78. = Item 76 + Item 77 = 906 + 698 = 1,604

79. $= \frac{\text{Item } 76}{\text{Item } 34} = \frac{906}{9.07} = 99.9$

80. $= \frac{\text{Item } 77}{\text{Item } 35} = \frac{698}{14.93} = 46.7$

Item No.

81. $= \frac{\text{Item 78}}{\text{Item 1}} = \frac{1,604}{24} = 66.8$

82. = Item 79 x 1.34 = 99.9 x 1.34 = 133.85

83. = Item 80 x 1.34 = 46.6 x 1.34 = 62.6

84. = Item 81 x 1.34 = 66.8 x 1.34 = 89.5

85. $= \frac{\text{Item 82}}{\text{Item 50}} \times 100 = \frac{133.85}{214.3} = 62.5$

86. $= \frac{\text{Item 83}}{\text{Item 51}} \times 100 = \frac{62.6}{85.4} \times 100 = 73.25$

87. $= \frac{\text{Item 84}}{\frac{\text{Item 54}}{\text{Item 1}}} \times 100 = \frac{89.5}{\frac{3219}{24}} \times 100 = 66.8$

88. = Item 84 x 2,545 = 89.5 x 2,545 = 228,000

89. $= \frac{\text{Item 88}}{\text{Item 29}} \times 100 = \frac{228,000}{1,486,000} \times 100 = 15.34$

90. $= \frac{\text{Item 23}}{\text{Item 78}} = \frac{3042}{1604} = 1.894$

91. $= \frac{\text{Item 9}}{\text{Item 78}} = \frac{1,557.7}{1,604} = 0.971$

92. $= \frac{\text{Item 57}}{\text{Item 78}} = \frac{1,562.75}{1,604} = 0.974$

93. = Item 91 + Item 92 = 0.971 + 0.974 = 1.945

95. $= \frac{\text{Item 94} \times 100}{2000} = \frac{4.50 \times 100}{2000} = 0.225$

96. = Item 90 x Item 95 = 1.894 x 0.225 = 0.427

Item No.

98. $= \frac{\text{Item 97} \times 100}{\text{Item 78}} = \frac{7.42 \times 100}{1{,}604} = 0.462$

99. $=$ Item 96 + Item 98 $= 0.427 + 0.462 = 0.889$

100. $= \frac{\text{Item 78}}{285 \times 24} \times 100 = \frac{1{,}604}{285 \times 24} \times 100 = 23.45$

TABLE NO. 2. HEAT BALANCES

(Hourly values are used in this table)

	Test #1 B.t.u.	Test #1 per-cent	Test #2 B.t.u.	Test #2 per-cent	Test #3 B.t.u.	Test #3 per-cent
Debit:-						
1. To heat fired to producer in fuel	1,468,000	100	1,173,000	100	1,172,000	100
Credit:-						
2. By heat equivalent of average output	227,800	15.3	180,200	15.4	140,700	12.0
3. By heat lost through scrubber water	79,400	5.3	57,150	4.9	31,760	2.8
4. By heat lost through jacket water	264,500	17.8	231,000	19.7	167,000	14.2
5. By heat lost through mechanical friction in engines and generators and electrical losses (= Difference between heat equivalent of output at switchboard and indicated horsepower output)	113,200	7.6	66,800	5.7	19,600	1.7
6. By unaccounted for losses (By difference)	801,100	54.0	637,850	54.3	812,940	69.3
	1,486,000	100.0	1,173,000	100.0	1,172,000	100.0

TABLE NO. 3.

PLANT ECONOMIES AS DETERMINED BY THE TESTS.

		Test #1	Test #2	Test #3
1.	Total output of test, kilowatt-hours	1604	1268	990
2.	Station load factor, percent	27.5	21.7	16.95
3.	Total coal fired to producers, pounds	3042	2450.5	2276
4.	Coal per kilowatt-hour, pounds	1.894	1.932	2.298
5.	Cost of fuel per kilowatt-hour, at $4.50 per ton, in cents	0.427	0.435	0.517
6.	Cost of labor per kilowatt-hour, figured upon a total labor cost of $7.42 per day, in cents	0.462	0.586	0.75
7.	Sum of fuel and labor costs, cents per kilowatt-hour	0.889	1.021	1.26
8.	Scrubber water used, cubic feet per kilowatt-hour	0.971	0.898	1.102
9.	Jacket water used, cubic feet per kilowatt-hour	0.974	1.23	1.22
10.	Total water used, exclusive of vaporizer water, in cubic feet per kilowatt-hour	1.945	2.128	2.322
11.	Thermal efficiency of plant from coal pile to switchboard, in percent	15.3	15.4	12.0

TABLE NO. 4. STATION RECORD FOR GAS POWER INSTALLATION

Month	Monthly Max. kw.	Ave. Daily Max. kw.	Total Output kw.hr.	Ave. Daily Output kw.hr.	Total Coal Used lbs.	Coal Used lb.per kw.hr.	Total Cost ¢ per kw.hr.	Coal Cost ¢ per kw.hr
1908								
July	90	65	18310	591	83380	4.53	- - -	- - -
August	90	69	15310	638	62200	4.06	3.842	- - -
September	110	89	23440	782	88610	3.78	2.612	- - -
October	120	96.5	26930	869	105355	3.92	2.512	0.86
November	120	101	22248	970	74878	3.36	2.431	0.75
December	140	113.5	30500	1524	95405	3.13	2.226	0.69
1909								
January	130	98	32840	1060	105177	3.21	1.92	0.72
February	130	95	29530	1054	105236	3.57	1.69	0.798
March	130	103	30270	978	110080	3.64	1.935	0.82
April	130	99	27480	918	92440	2.98	2.12	0.966
May	110	92	25480	823	89480	3.50	1.96	0.883
June	110	80	10400	801	33080	3.25	2.46	1.25
July	100	80	24750	798	58200	2.35	1.62	0.53
August	120	79	25970	838	59540	2.30	1.56	0.518
September	140	110	32540	1083	64840	2.00	- - -	0.437
October	140	110	35700	1152	78200	2.18	- - -	0.492
November	160	128	38070	1270	73980	1.94	- - -	0.532
December	170	134	42510	1372	77460	1.82	- - -	0.542
1910								
January	150	114	37470	1210	78480	2.10	- - -	0.673
February	120	110	34850	1244	78230	2.23	- - -	0.724

Notes:- August, 1908, 24 days record - steam rig on from 24th. November, 1908, 23 days record. December, 1908, 20 days record, only. June, 1909, 13 days record, only Steam rig was on the remainder of the month - 17 days. New 85-kw. unit was put in operation June 25th, 1909.

TABLE NO. 5.

ESTIMATED COST OF PRESENT INSTALLATION.

1.	Producers and scrubbers, erected	$ 5,400
2.	280-horsepower gas engine, erected	8,400
3.	100- " " " , "	3,600
4.	200-kilowatt generator with exciter	2,192
5.	85- " " " "	1,157
6.	Switchboard	1,500
7.	Motor-generator set	1,330
8.	Belts, 77' of 28", 3-ply and 60 1/2' of 14", 3-ply	400
9.	Building	2,000
10.	Auxiliaries and piping, ten percent of total first cost	2,281
	Total first cost	$ 28,800

TABLE NO. 6.

ESTIMATED COST OF OPERATION OF PLANT.

	Percent of First Cost	Yearly Costs Dollars	Cents per kw. hr. at Switchb'd
1. Fixed charges:-			
(a) Interest	5		
(b) Depreciation	8		
(c) Insurance and Taxes	1		
2. Maintenance and Repairs	2		
Total	16	4,608	1.296
3. Lubricating oil and waste			0.000
4. Fuel cost			0.600
5. Cost of cooling water			0.028
6. Attendance		2,760	0.777
Total estimated cost of power production			2.701

TABLE NO. 7.

CENTRAL STATION STATISTICS FOR COMPARISON.

(Taken from the "Electrical World", May, 1909)

Number 1	Capacity of Station, Kw 2	Population of City 3	Conn. Load, Kw./kw of 2 4	Same as 4, in Lamps 5	Same as 4, in Motors 6	Same as 4, Appliances 7	Same as 4, Transformer 8	Yearly Load Factor 9	Watts Station rating per Capita 10	Consumers per 100 Population 11	Residences Conn. per 100 Pop. 12
1	565	10000	1.94	0.87	1.06	.01	- -	- -	56	5.2	- -
2	300	5000	- -	- -	- -	- -	- -	- -	60	- -	10.
3	240	1500	2.20	1.54	0.37	.29	- -	- -	160	25.0	- -
4	850	10000	2.60	1.44	0.84	.32	- -	- -	85	14.8	10.4
5	250	4000	2.20	1.20	0.90	.10	1.2	.23	63	11.0	- -
6	255	5000	1.90	1.40	0.30	.20	1.8	.15	51	11.0	- -
7	300	800	1.90	1.60	0.30	- -	- -	.21	38	9.0	- -
8	394.3	6214	2.12	1.34	0.63	.185	1.5	.197	73.3	12.7	10.2
9	285	6000	2.58	1.66	0.82	.10	1.0	.245	45.7	6.95	4.3

Note:- Numbers one to seven are average Illinois and Iowa towns. Number eight is the average values of the numbers given in the column. Number nine shows the conditions at Hoopeston.

TABLE NO. 8.

ANALYSIS OF CONNECTED LOAD AT HOOPESTON AND ROSSVILLE.

Part 1. - Lighting Load at Hoopeston:-

Class of Service	Con-nections	No. of lamps 16-cp	No. of lamps Arcs	Kilowatts Conn.	Kilowatts Peak
Residence	271	4500		252	63
General business	50	920	1-30amp	57	57
Office, shop, factory, etc.	52	977	9-500 w	59	25
Churches and halls	19	1365		76.5	
Emergency	6	1050	10		
Street lighting		143	5	12.5	12.5
Miscellaneous				13	
Total peak load					157.5

Part 2. - Lighting Load at Rossville:-

Class of Service	Con-nections	No. of lamps 16-cp	No. of lamps Arcs	Kilowatts Conn.	Kilowatts Peak
Residence	190	1200		67	25
General Business	24	200		11.5	10
Office, shop, factory, etc.	10	20		1.1	
Churches and halls	9	950		54	
Street lighting				5	5
Total peak load					40

Part 3. - Power Load at Hoopeston:- The power load at Hoopeston consists of 23 kilowatts of irons, fans, etc., connected, none of which can be considered peak load, and 25 single-phase motors totaling 16 horsepower, 13 three-phase motors totaling 170 horsepower and 14 direct current motors totaling 125 horsepower. About 80 of the 232 kilowatts can be considered peak load.

PLATE 1

Curves showing the records of operation for the gas power installation as presented in Table 4.

Curve No.

1. Total monthly output, kw.-hr.
2. Maximum peak, kw.
3. Average peak, kw.
4. Average daily output, kw.-hr.
5. Coal burned per kw.-hr., lbs.
6. Cost of power production, cts. per kw.-hr

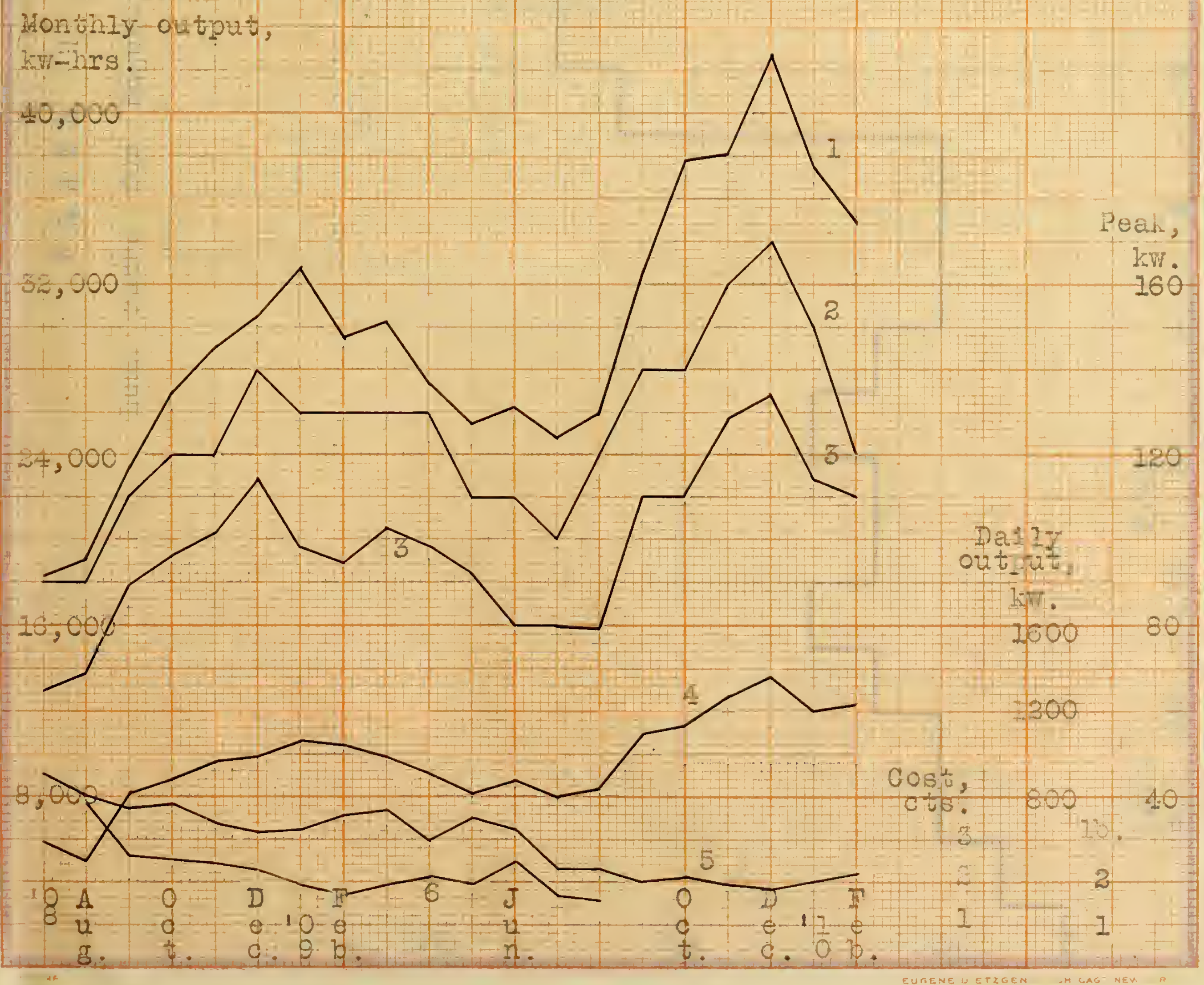
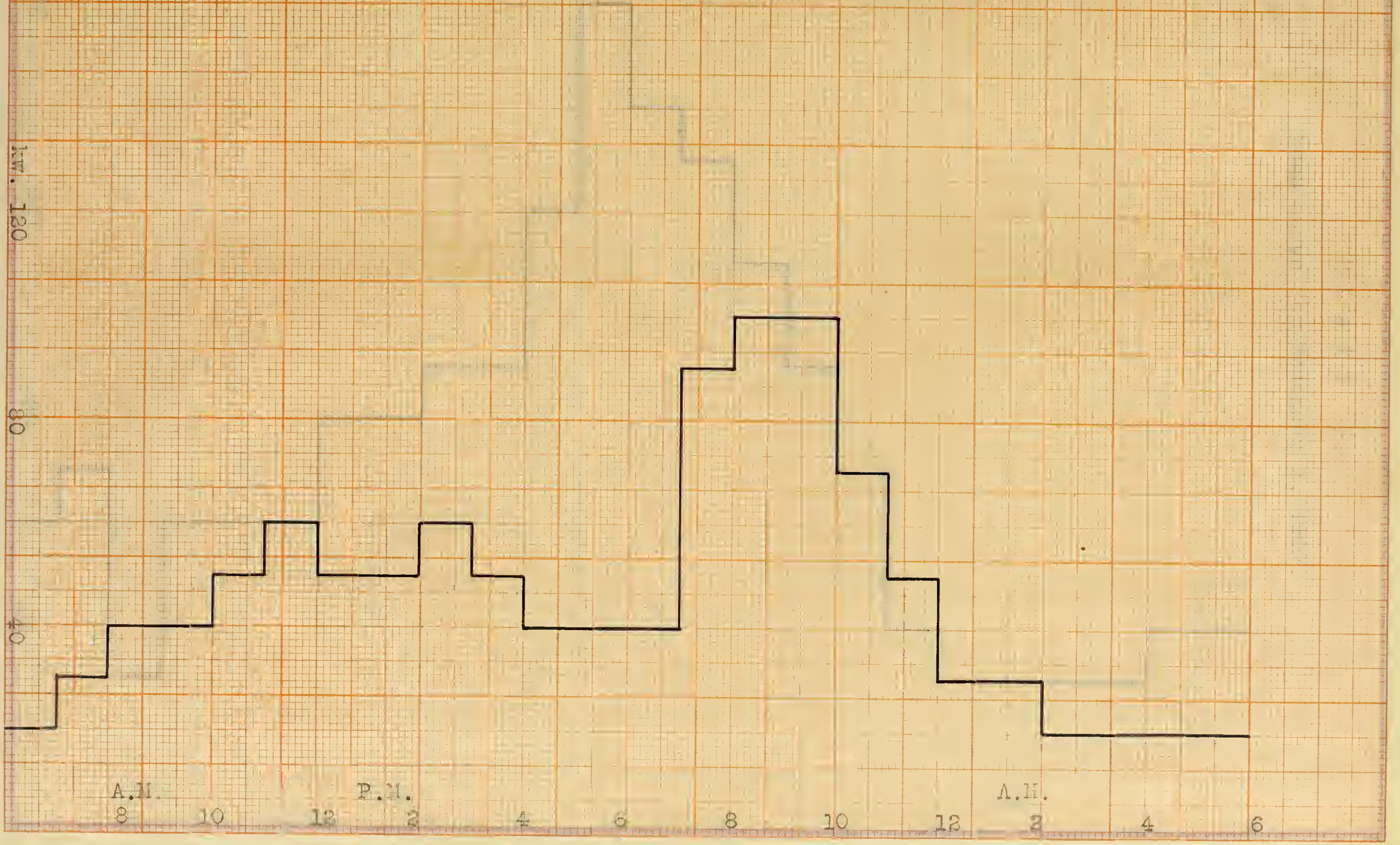


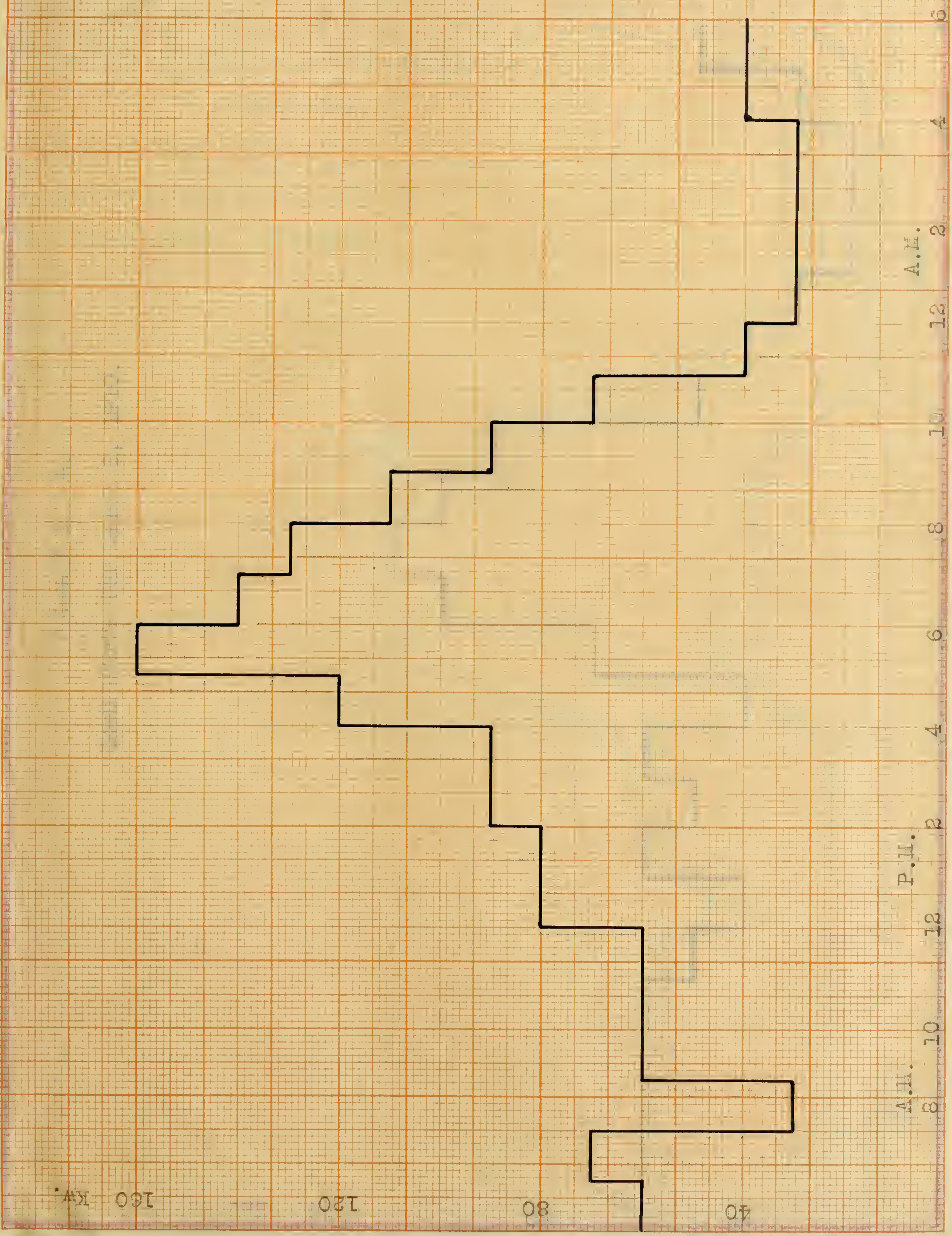
PLATE 2.

Load curve for August 20, 1909.



P L A T E 3.

Load curve for December 3, 1909.



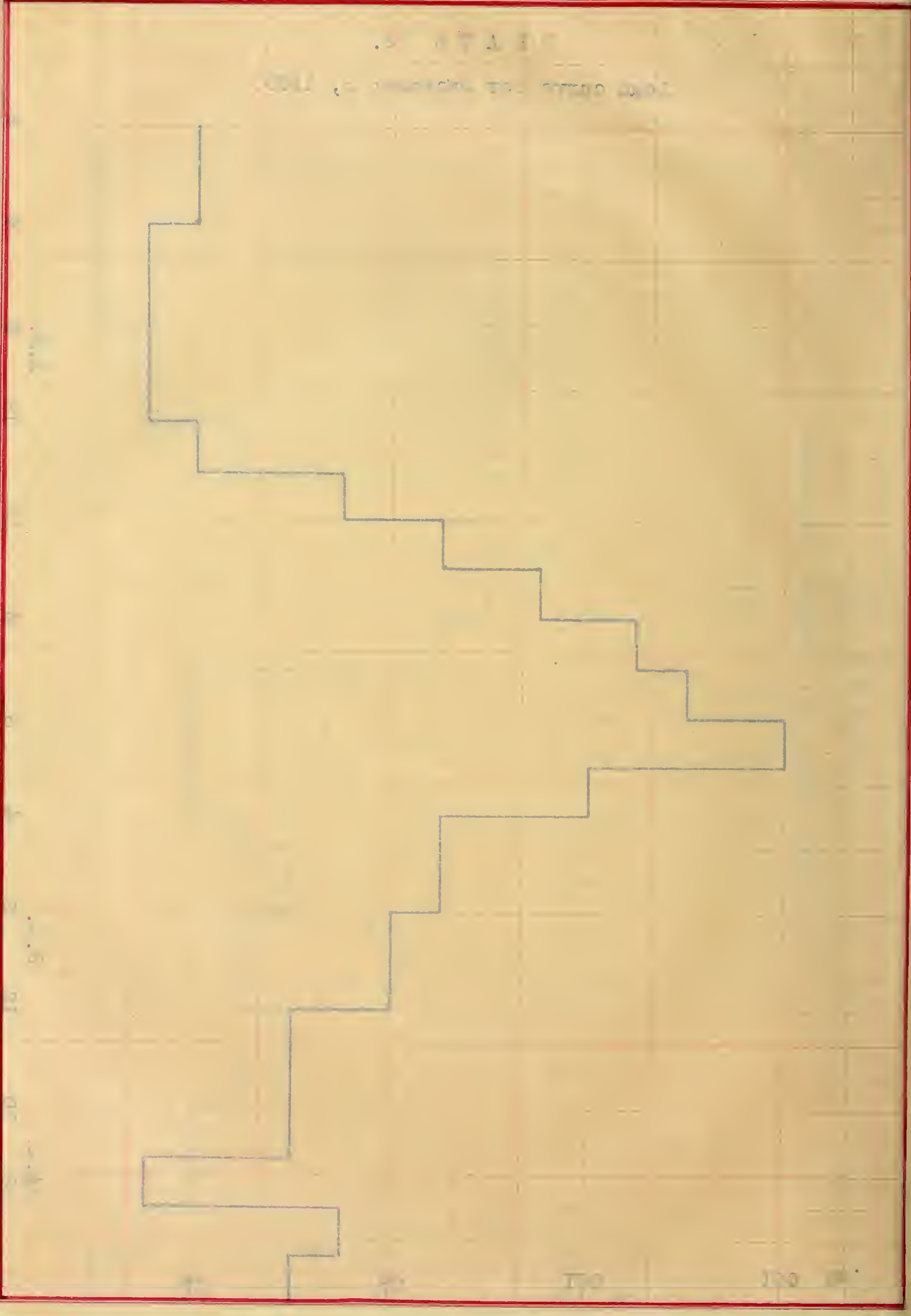
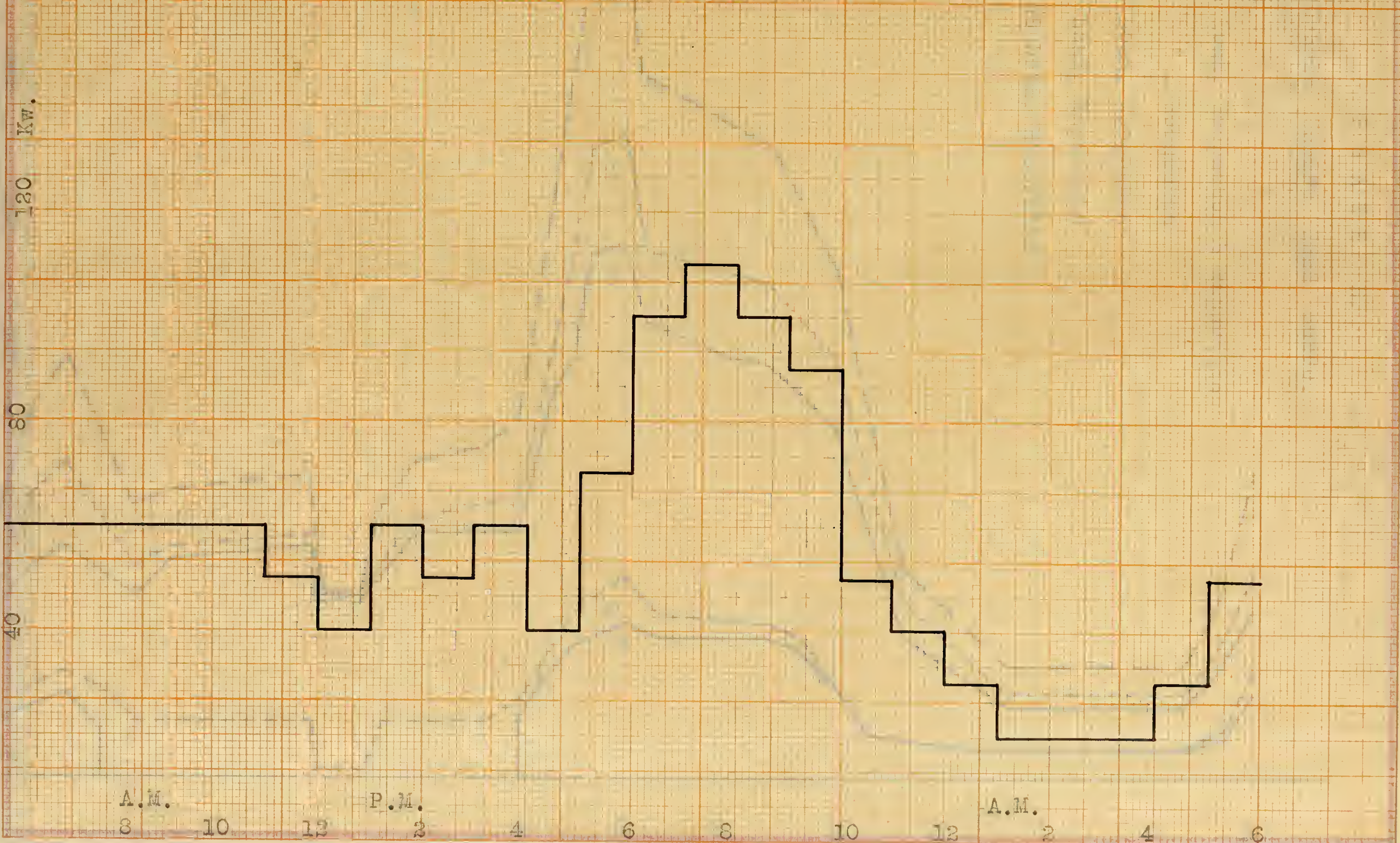
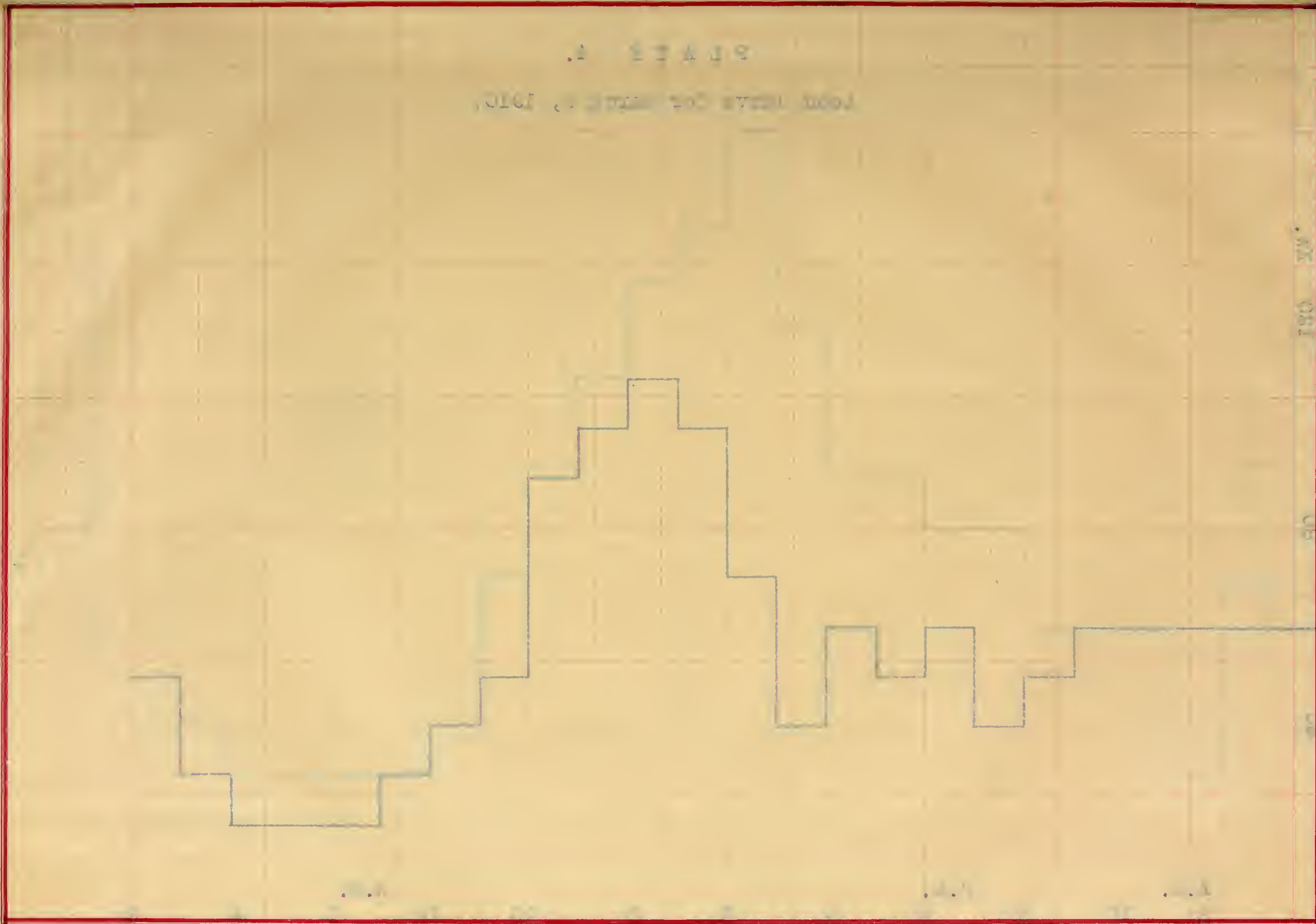


PLATE 4.

Load curve for March 8, 1910.



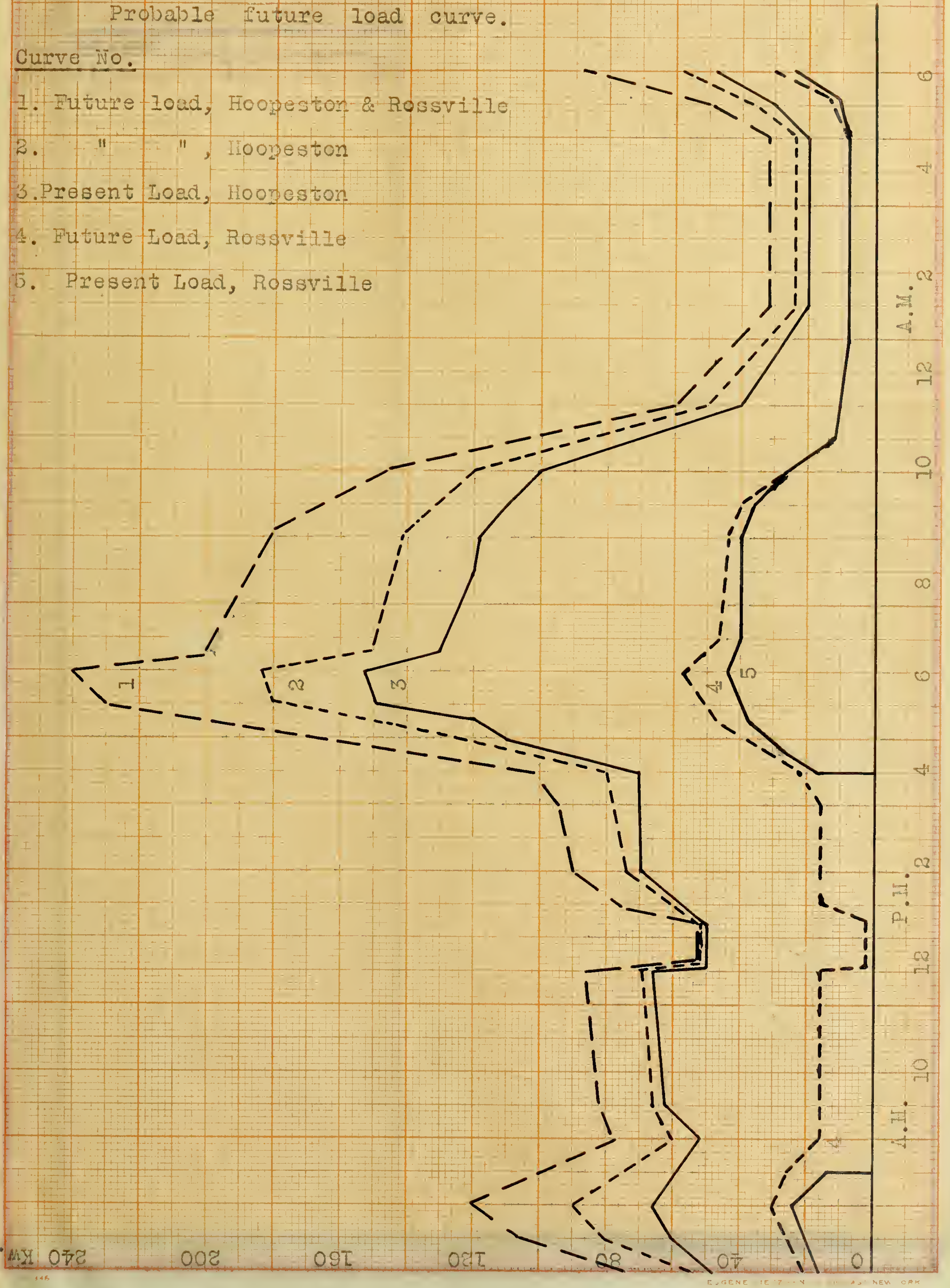


P L A T E 5.

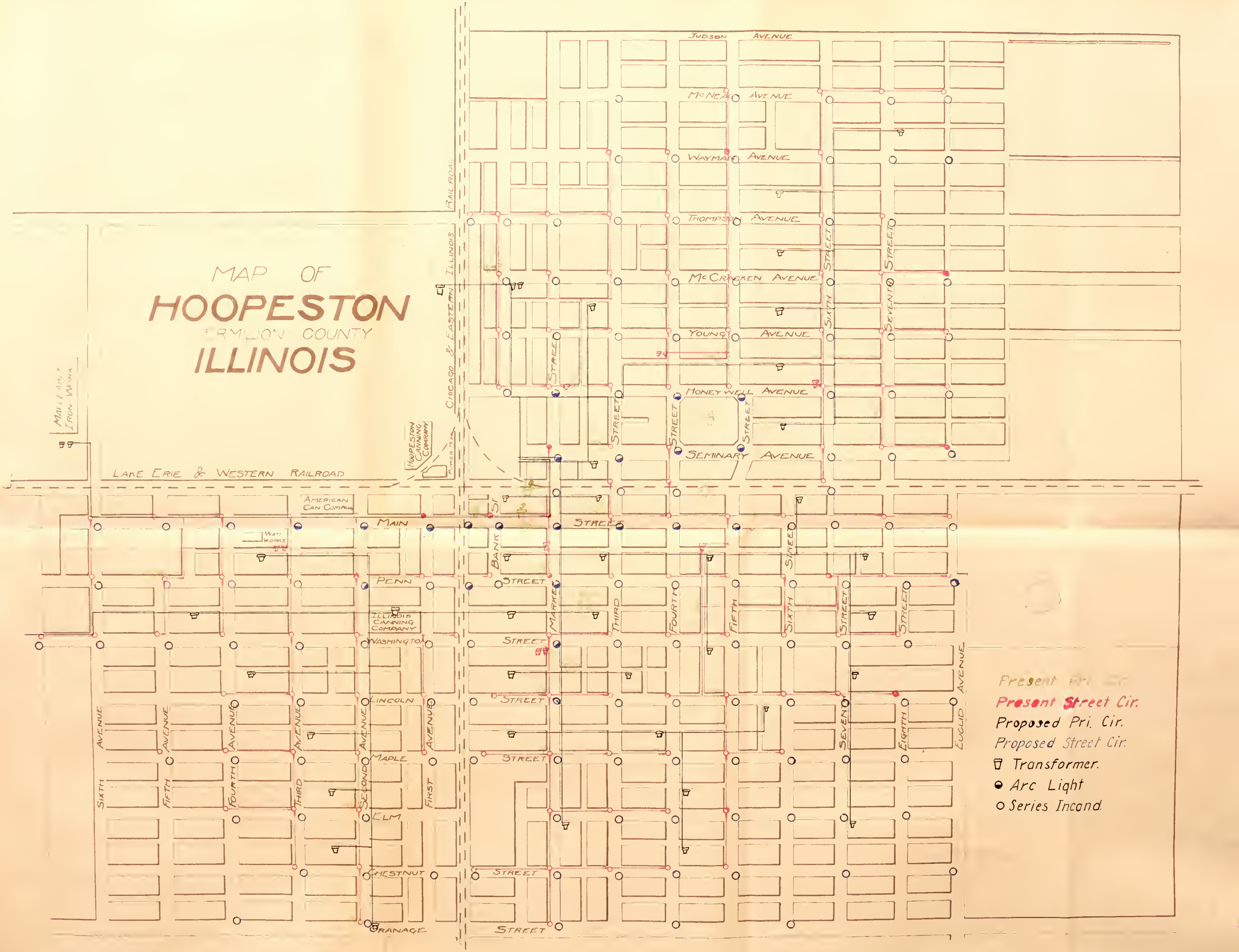
Probable future load curve.

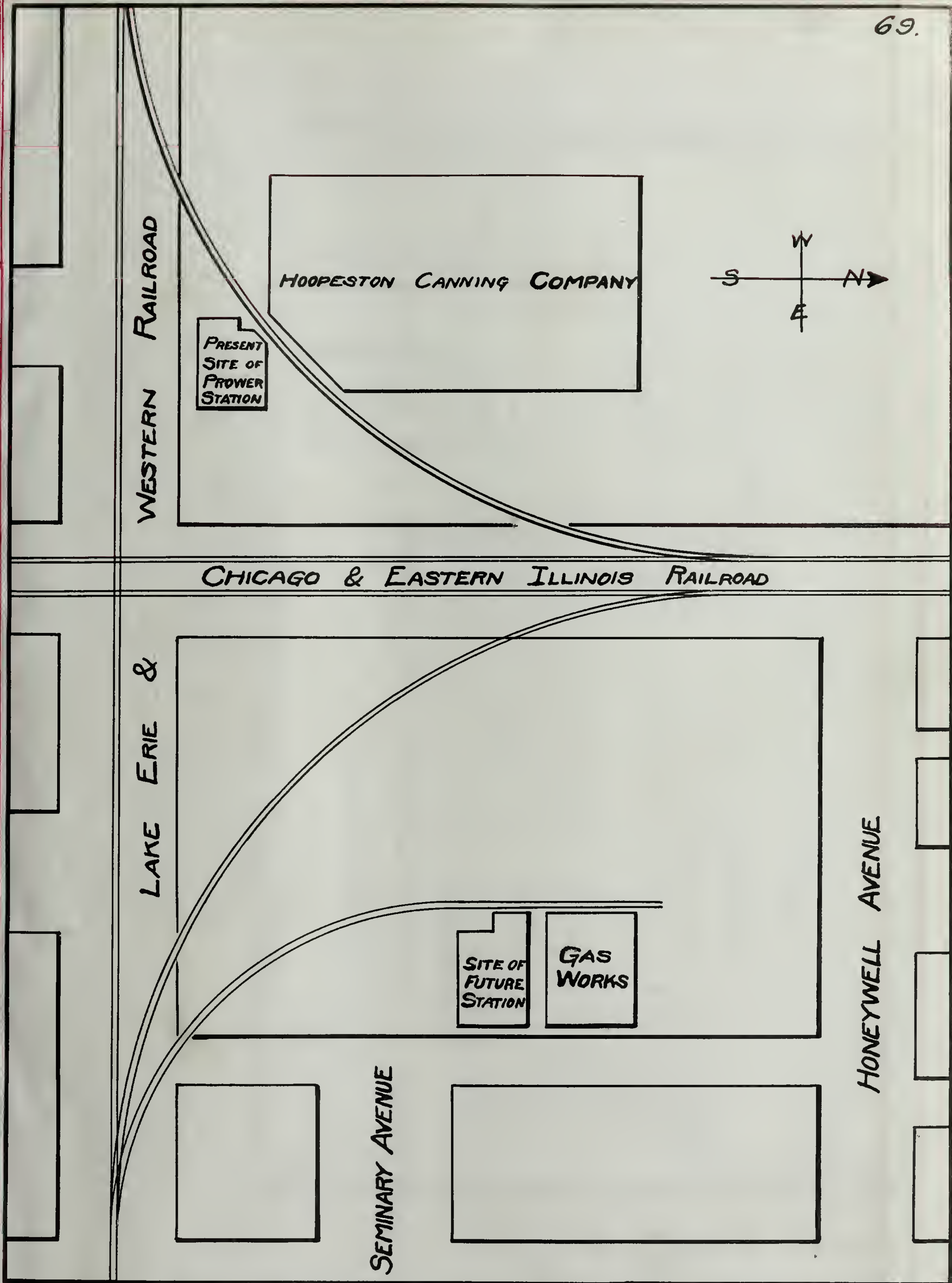
Curve No.

1. Future load, Hoopeston & Rossville
2. " " , Hoopeston
3. Present Load, Hoopeston
4. Future Load, Rossville
5. Present Load, Rossville



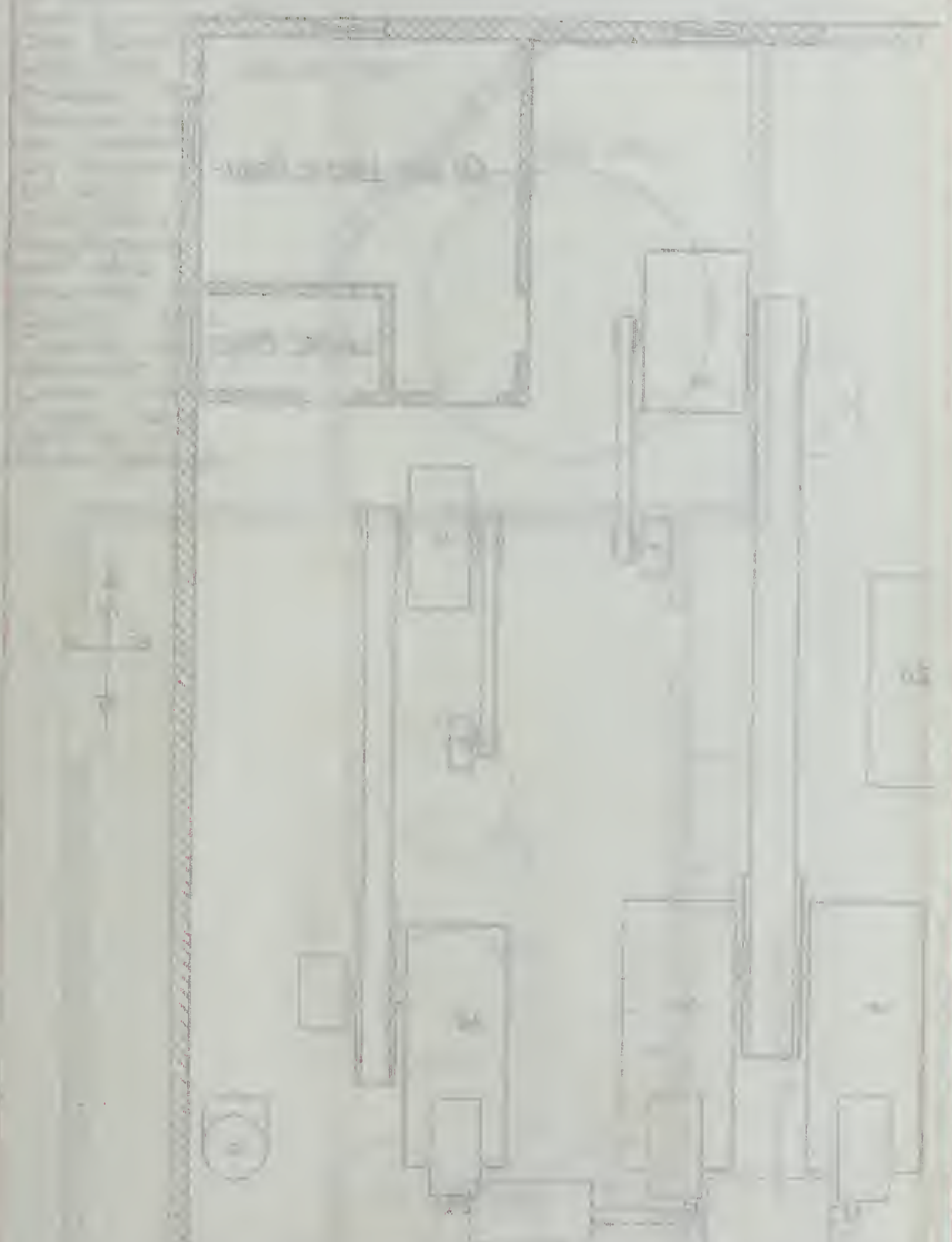

AVENUE

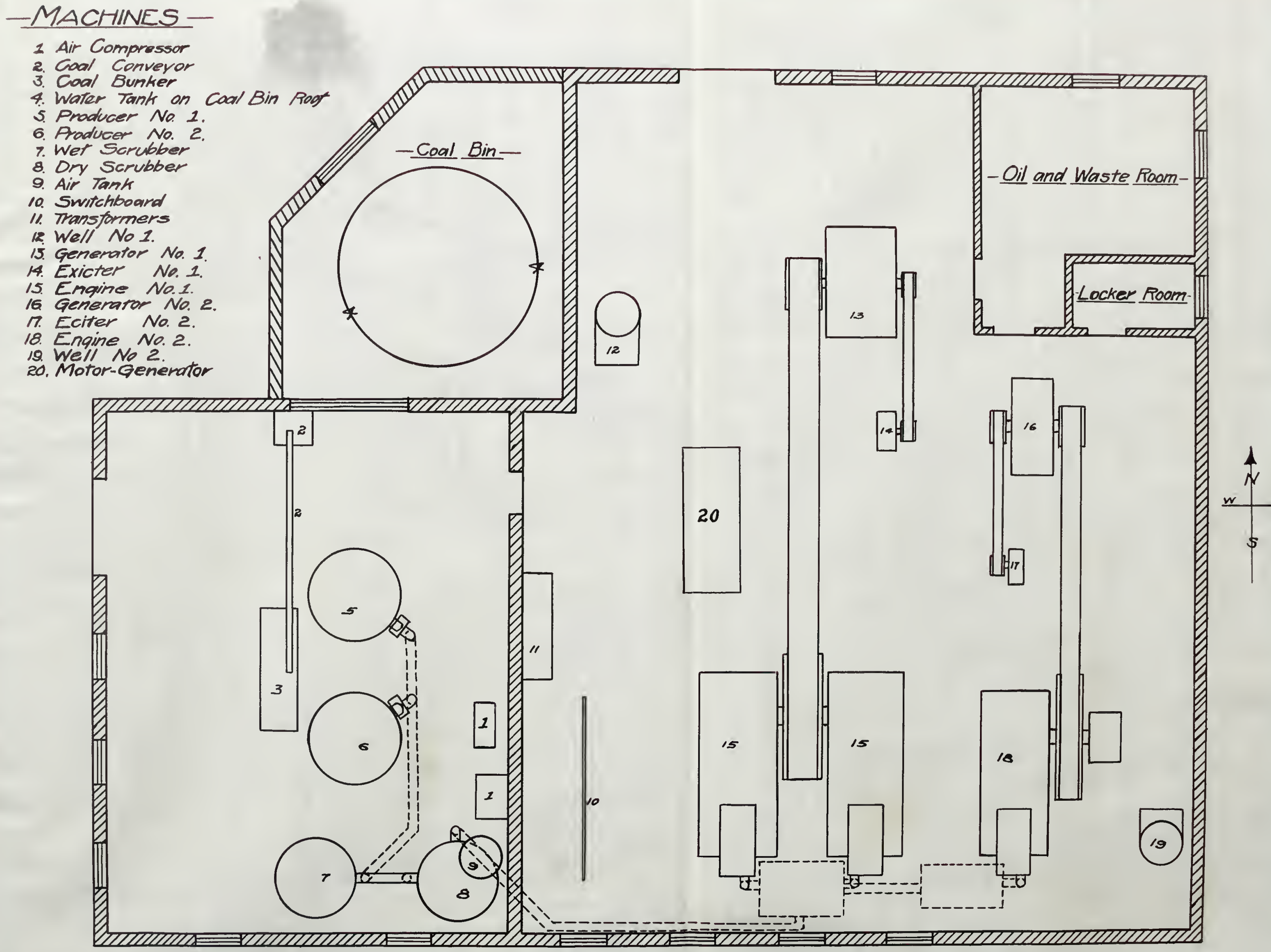

MAP OF
HOOPESTON
ILLINOIS
JUDSON AVENUE
McNEAL AVENUE
WAYMAN AVENUE
THOMPSON AVENUE
McCRACKEN AVENUE
YOUNG AVENUE
HONEYWELL AVENUE
SEMINARY AVENUE
CHICAGO & EASTERN ILLINOIS RAIL ROAD
LAKE ERIE & WESTERN RAILROAD
HOOPESTON CANNING COMPANY
AMERICAN CAN COMPANY
MAIN STREET
PENN STREET
WASHINGTON STREET
LINCOLN STREET
MAPLE STREET
ELM
CHESTNUT STREET
GRANAGE STREET
ILLINOIS CANNING COMPANY
BANK ST
MARKET
THIRD
FOURTH
FIFTH
SIXTH STREET
SEVENTH STREET
EIGHTH
EUCLID AVENUE
SIXTH AVENUE
FIFTH AVENUE
FOURTH AVENUE
THIRD AVENUE
SECOND AVENUE
FIRST AVENUE
Present Street Cir.
Proposed Pri. Cir.
Proposed Street Cir.
Transformer.
Arc Light
Series Incand.



AN ENLARGED MAP OF SITE

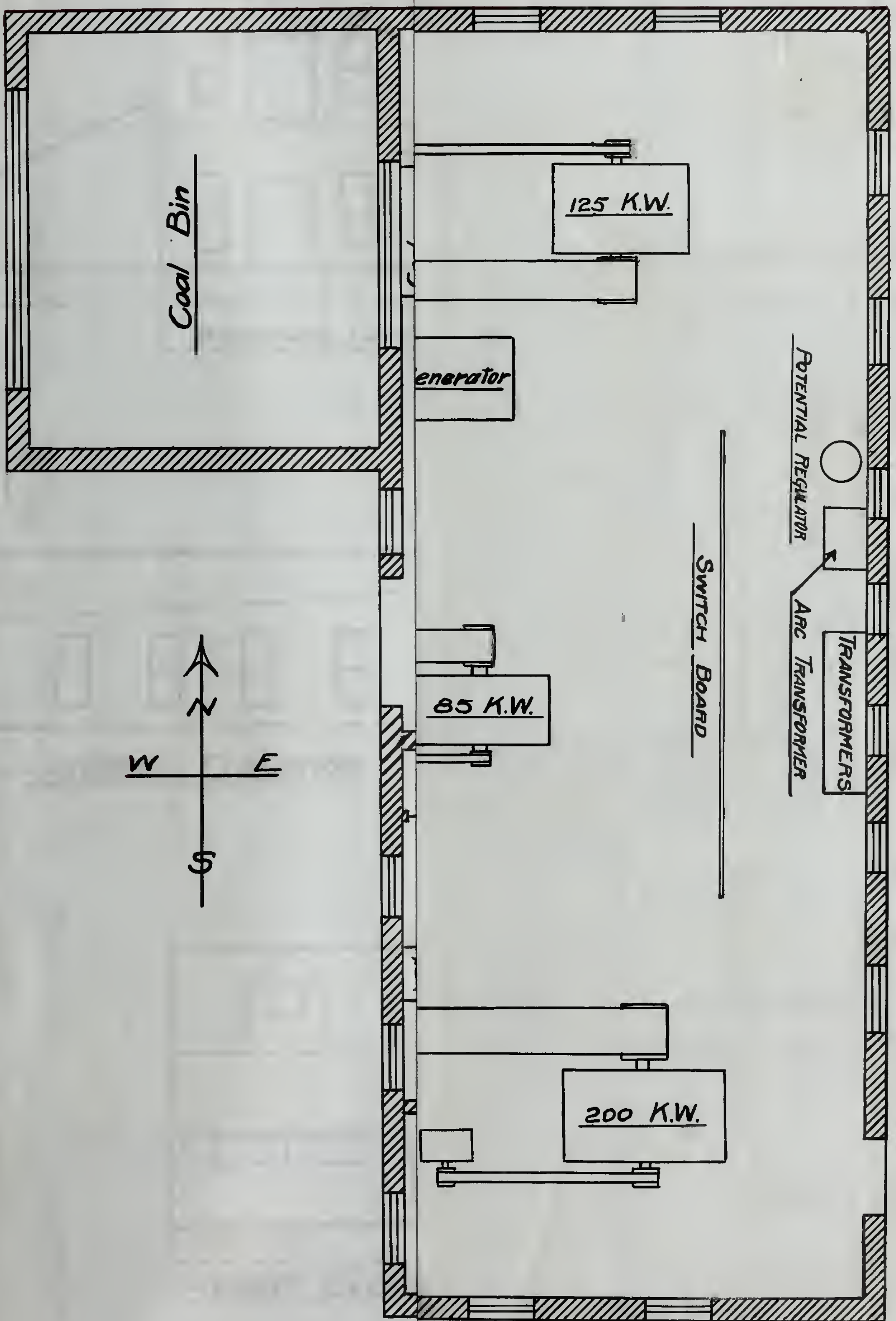
Scale ~ 1 in. = 125 ft.





—FIG. 1 —PRESENT FLOOR PLAN OF POWER PLANT—

—Scale — — $\frac{1}{8}'' = 1'$—



POWER STATION

Scale ~ ~ $\frac{1}{8}$ in. = 1 ft.

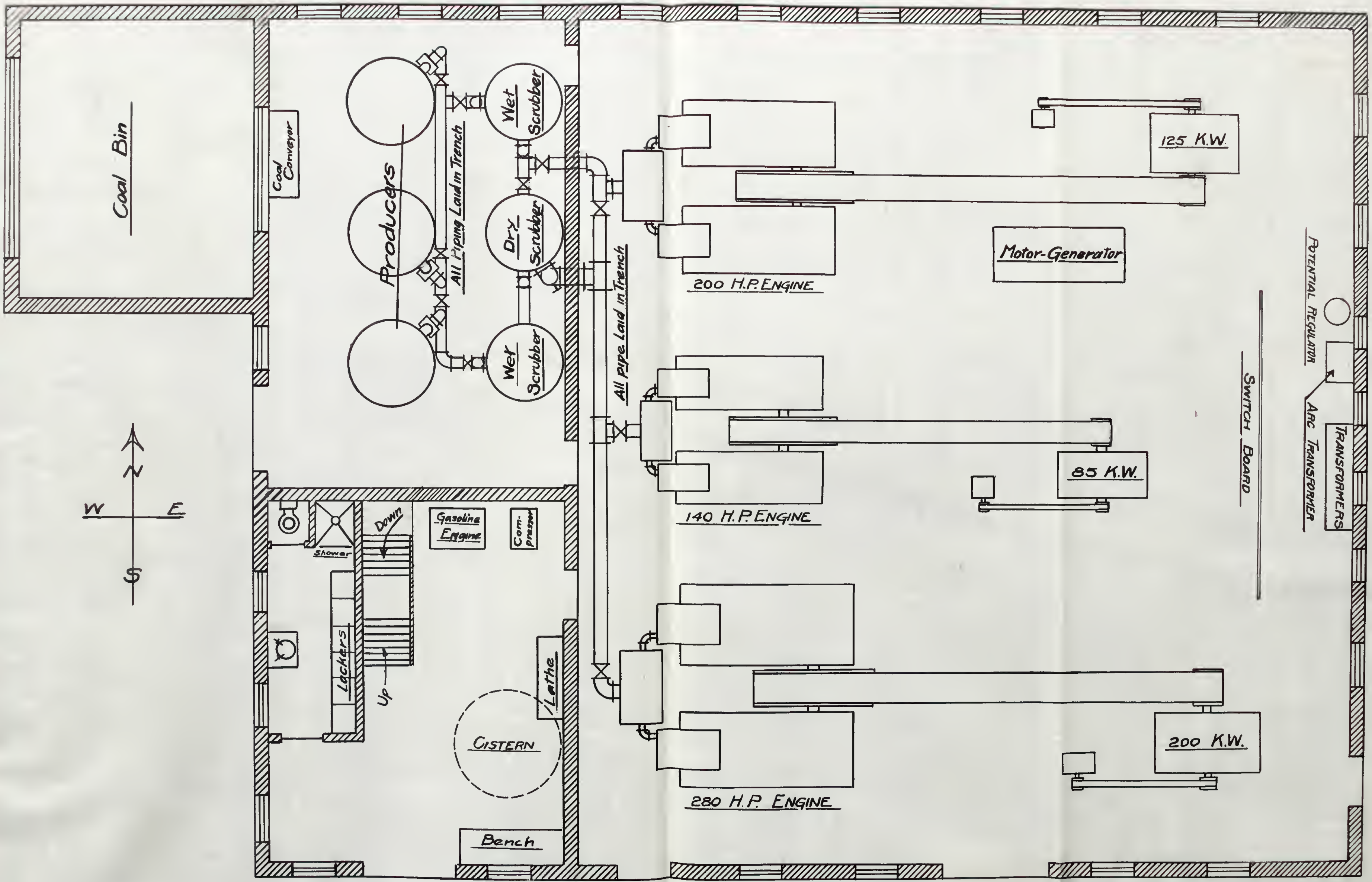
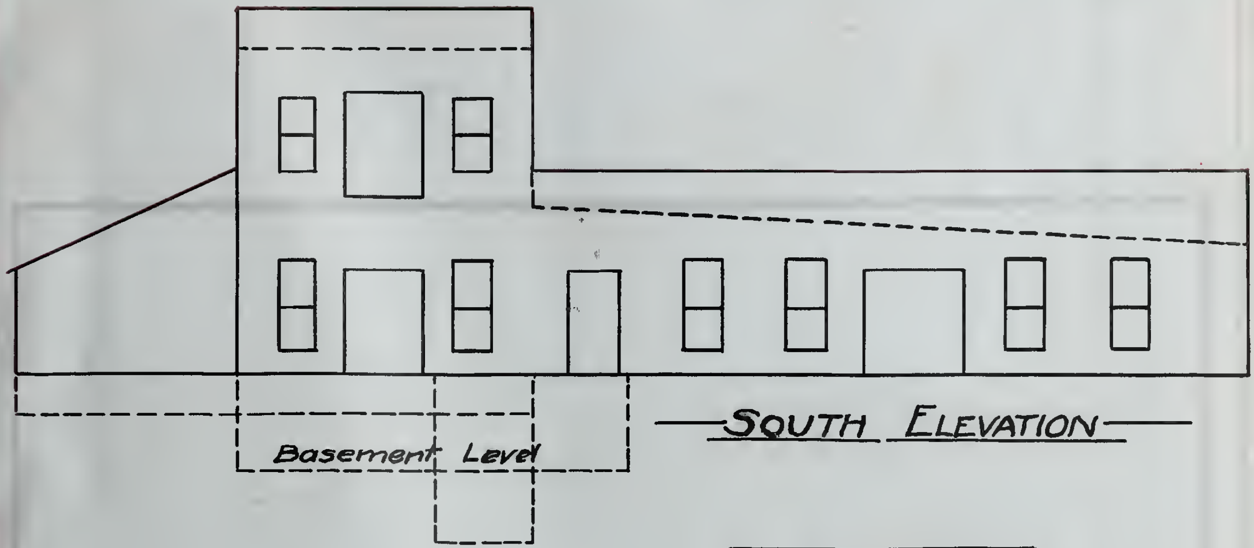
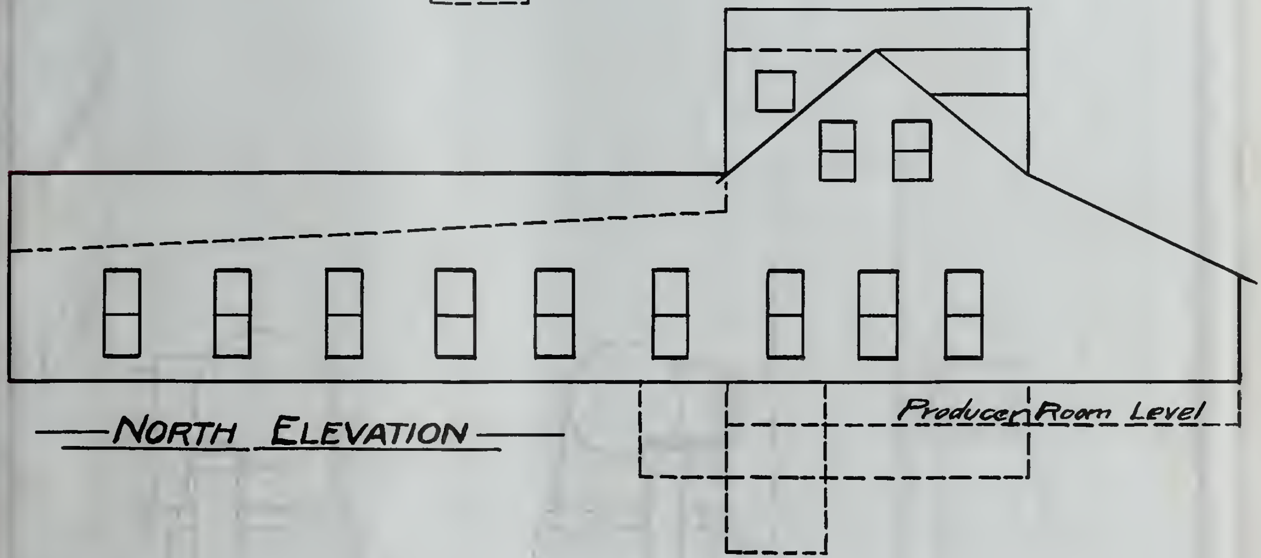


FIG. 2 — PROPOSED FLOOR PLAN OF POWER STATION

Scale ~ $\frac{1}{8}$ in. = 1 ft.





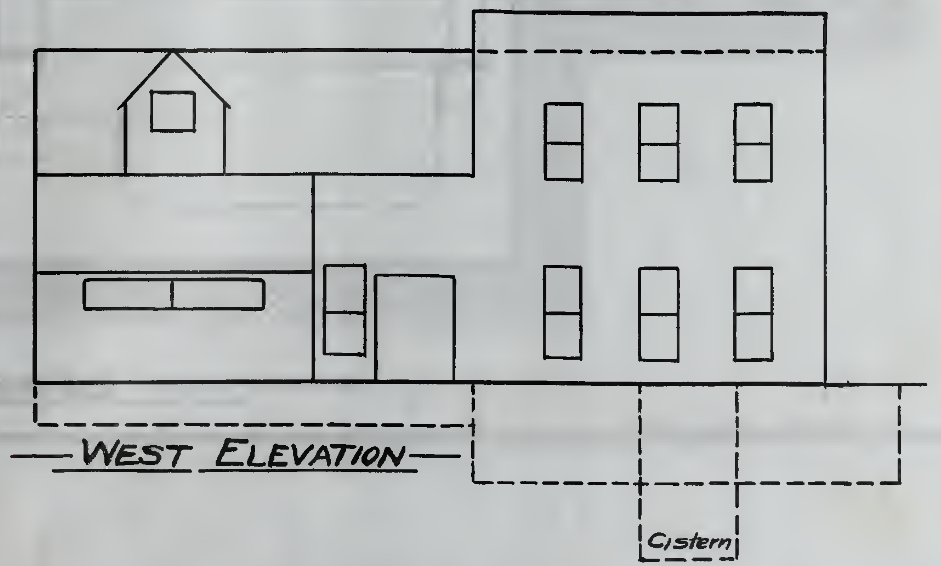
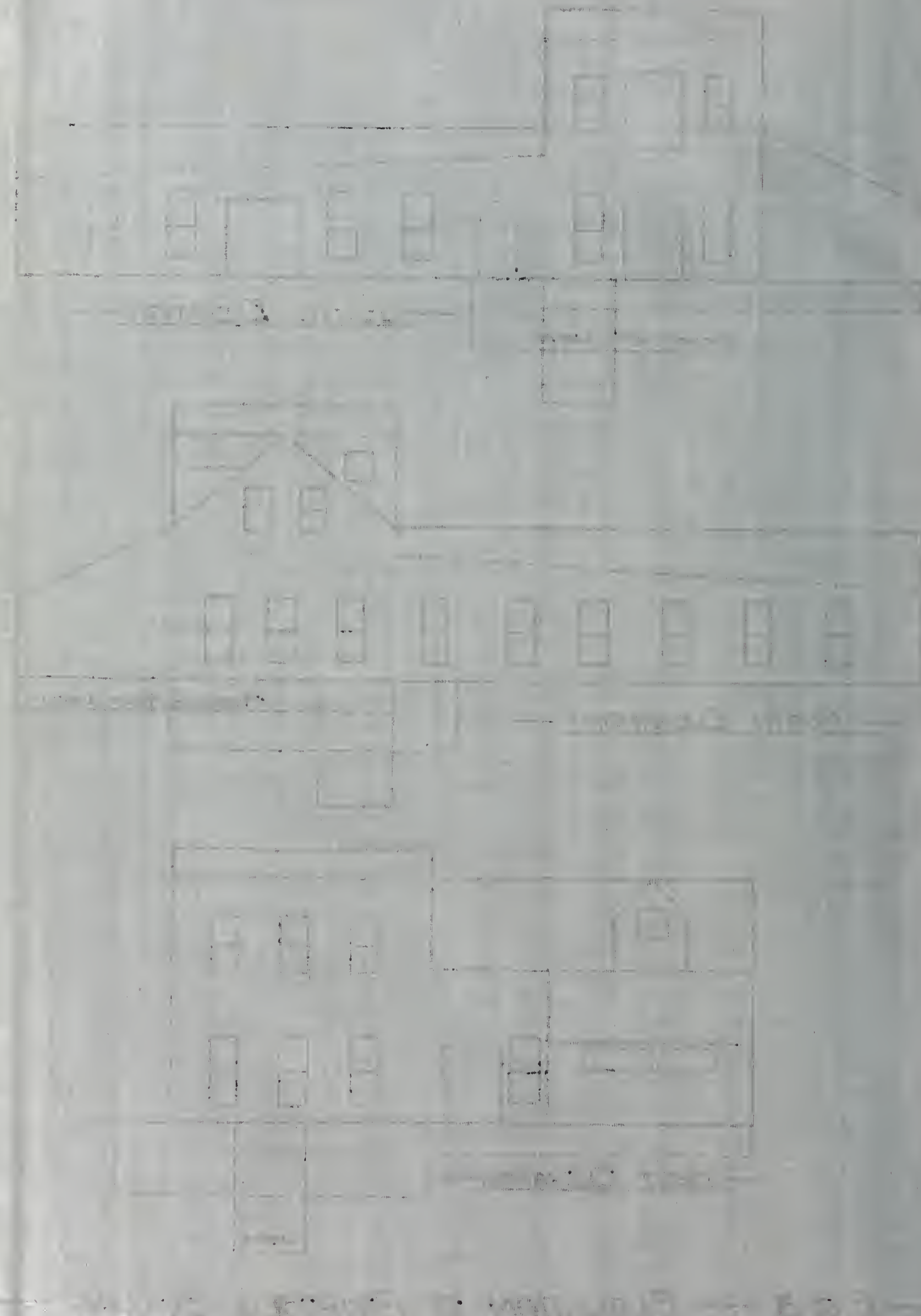
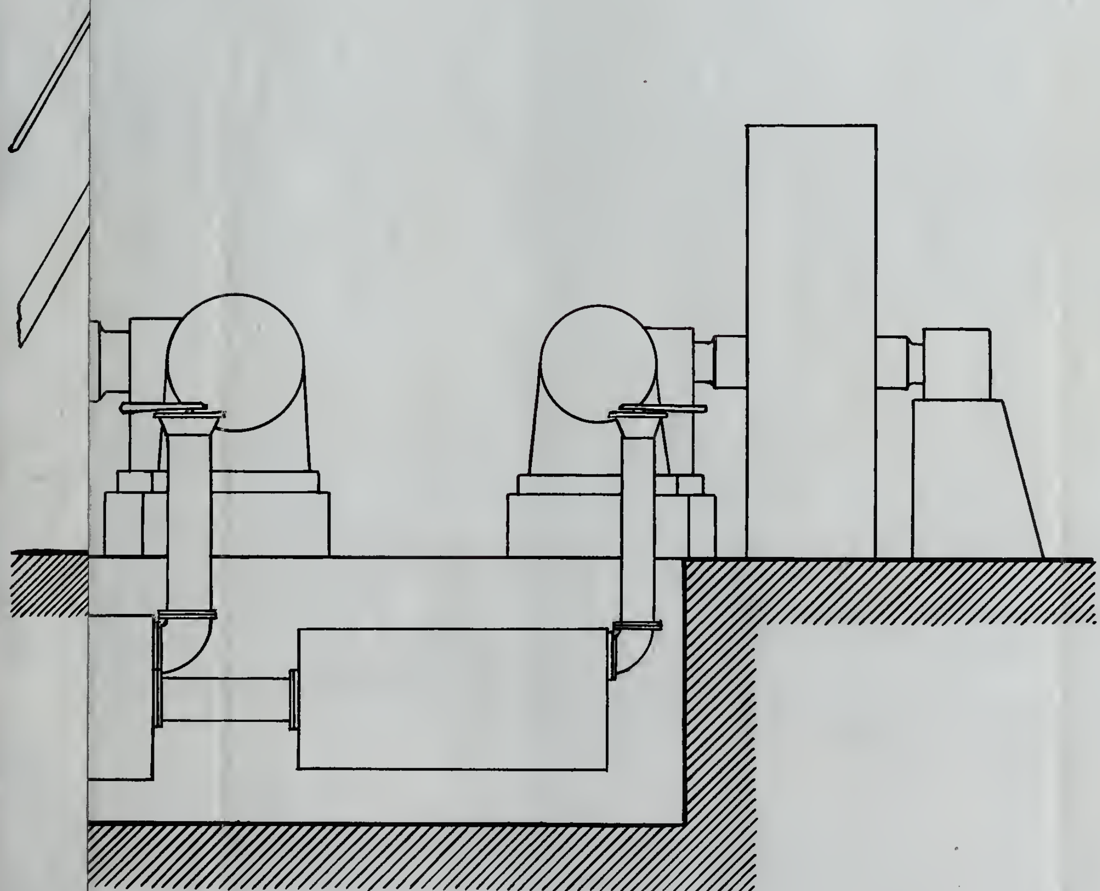


FIG. 3 — ELEVATION OF PROPOSED BUILDING





PPARATUS

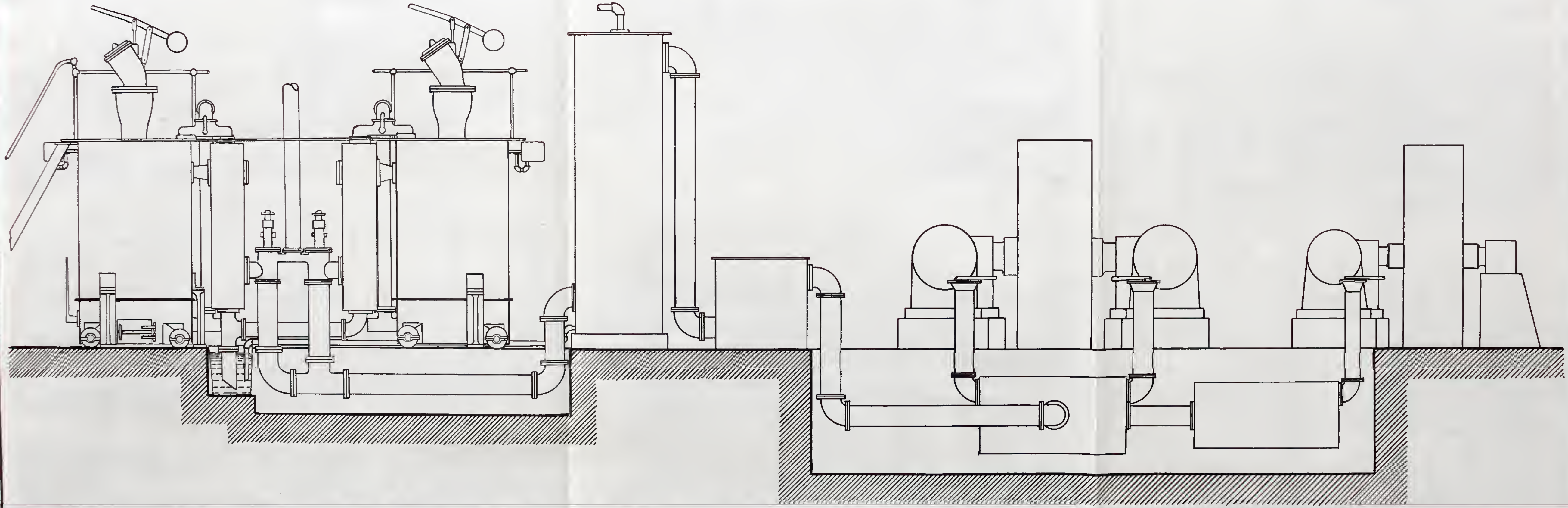
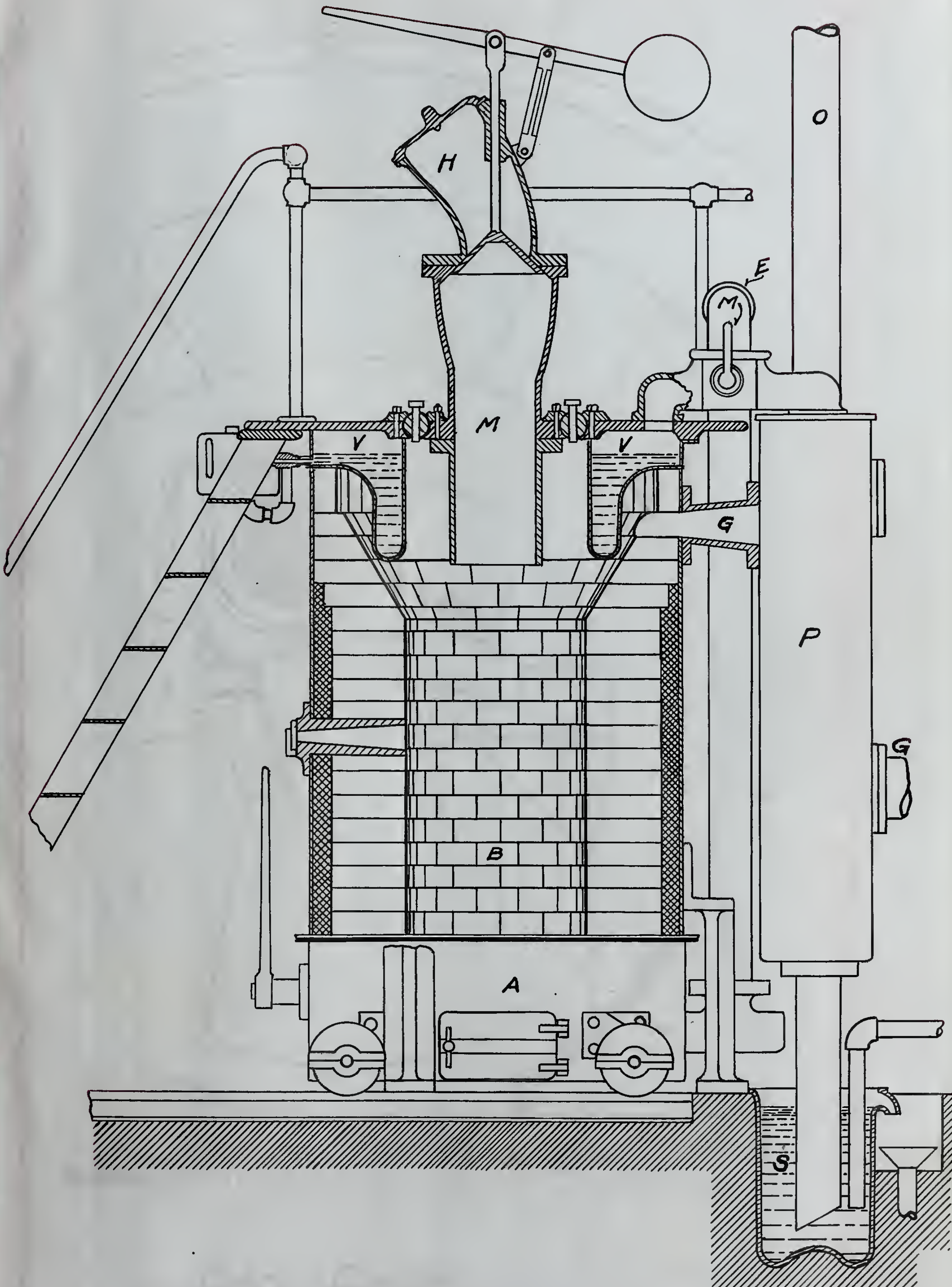
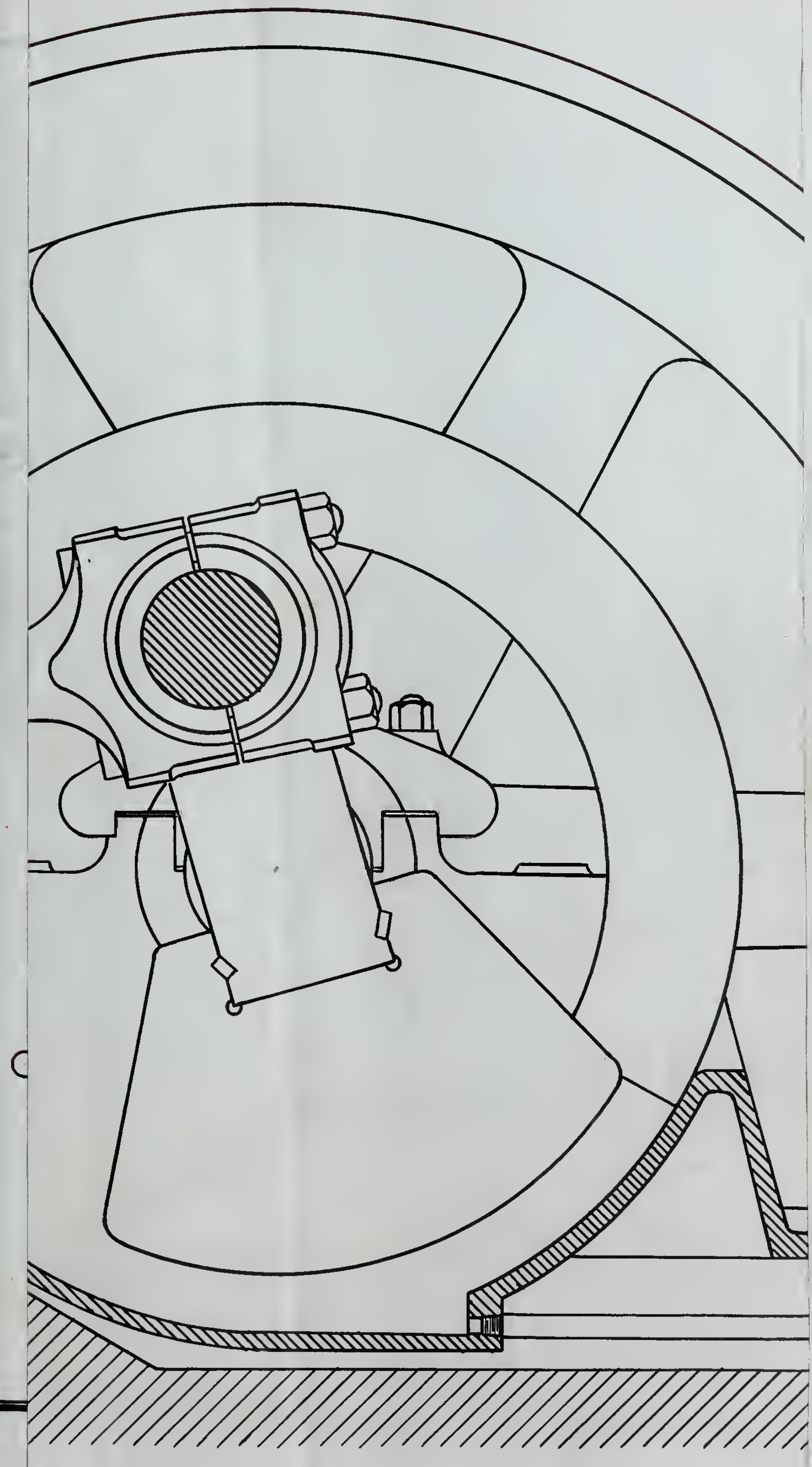


FIG. 4 — DIAGRAMMATICAL ELEVATION OF PRESENT APPARATUS



—FIG. 5 —SECTION OF MUENZEL GAS PRODUCER—



GAS ENGINE

SCALE ~ 1" = 1'

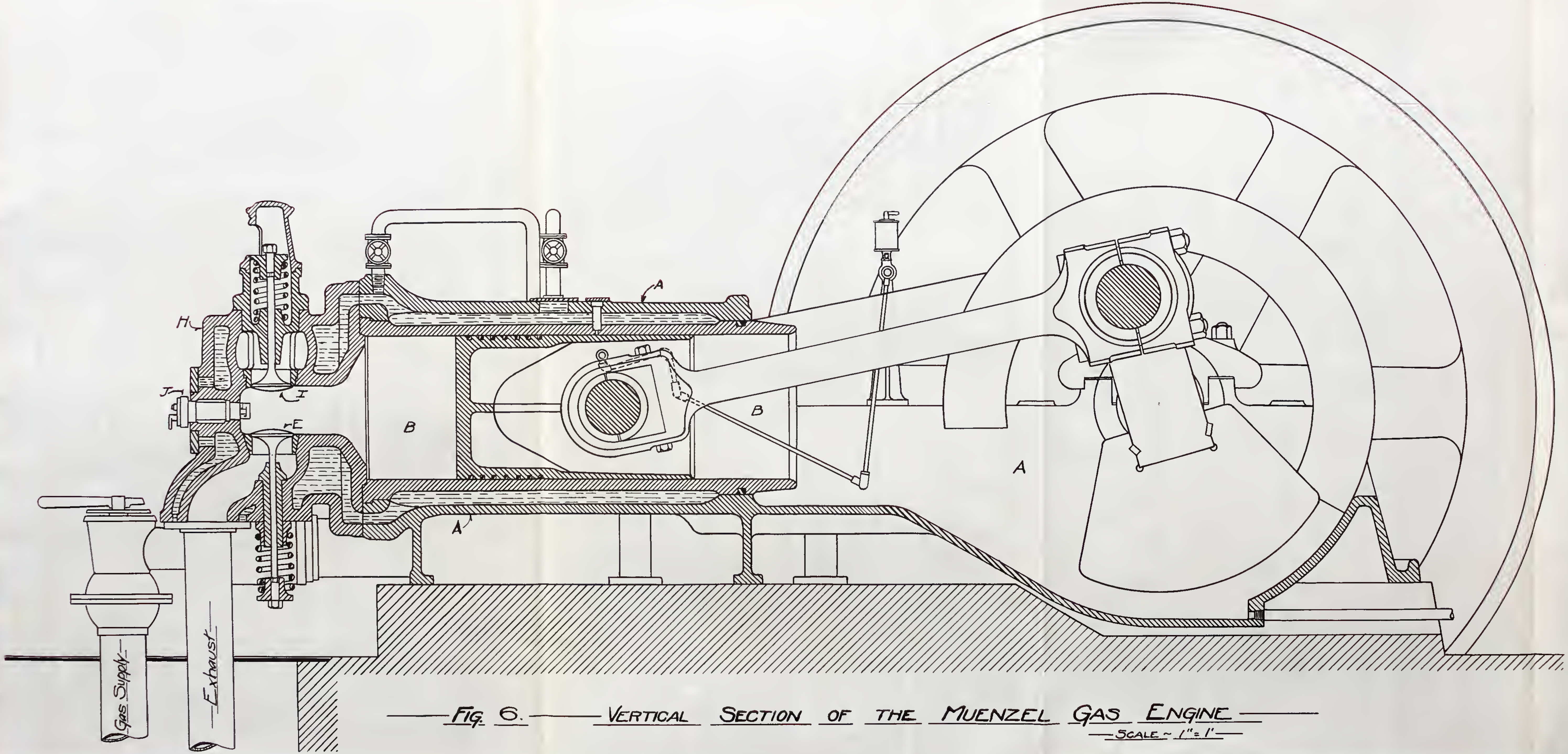
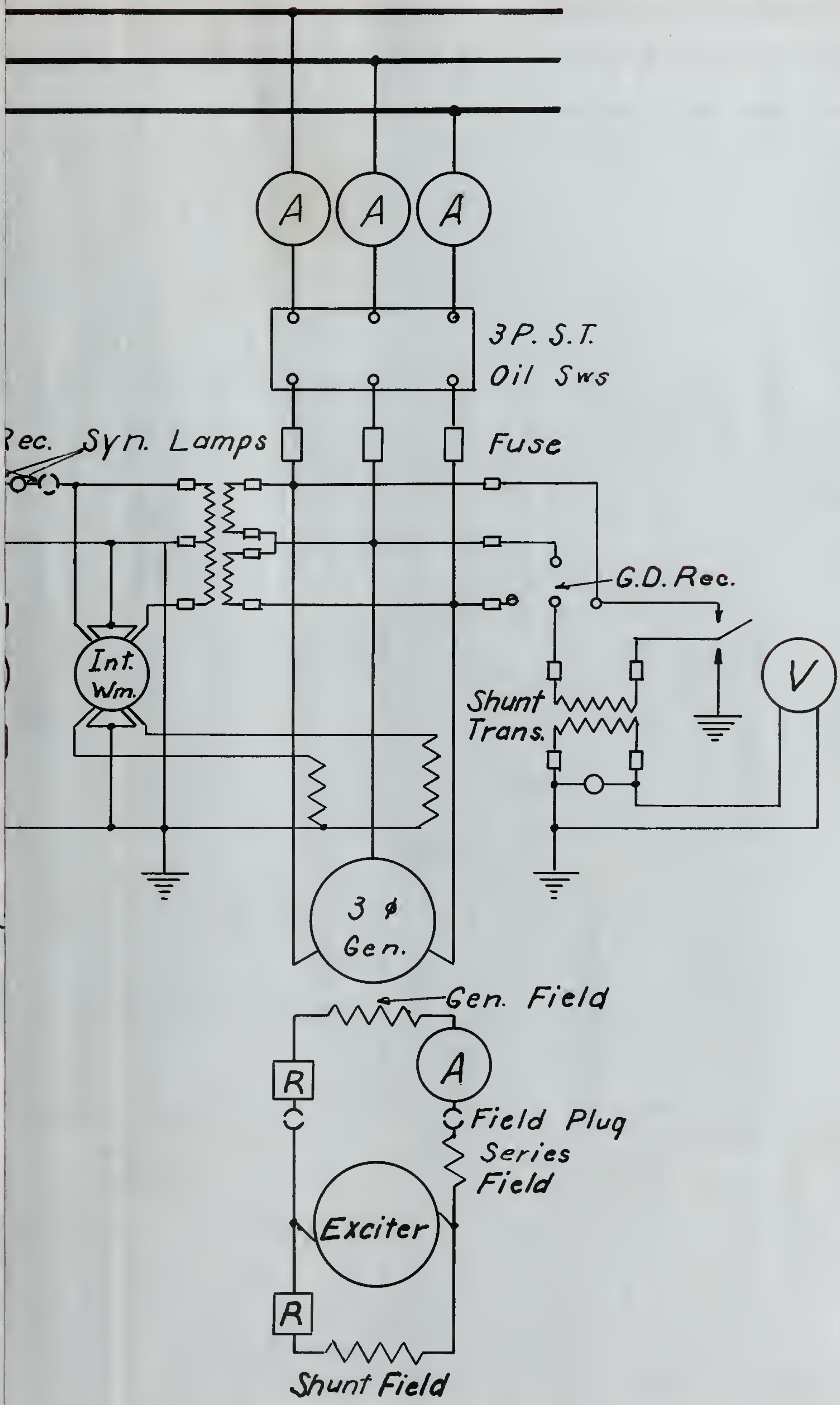


Fig. 6. VERTICAL SECTION OF THE MUENZEL GAS ENGINE

SCALE ~ 1" = 1'



A
A
A
3P. S.T.
Oil Sws
Rec.
Syn. Lamps
Fuse
G.D. Rec.
Int.
Wm.
V
Shunt
Trans.
3 φ
Gen.
Gen. Field
R
A
Field Plug
Series
Field
Exciter
R
Shunt Field

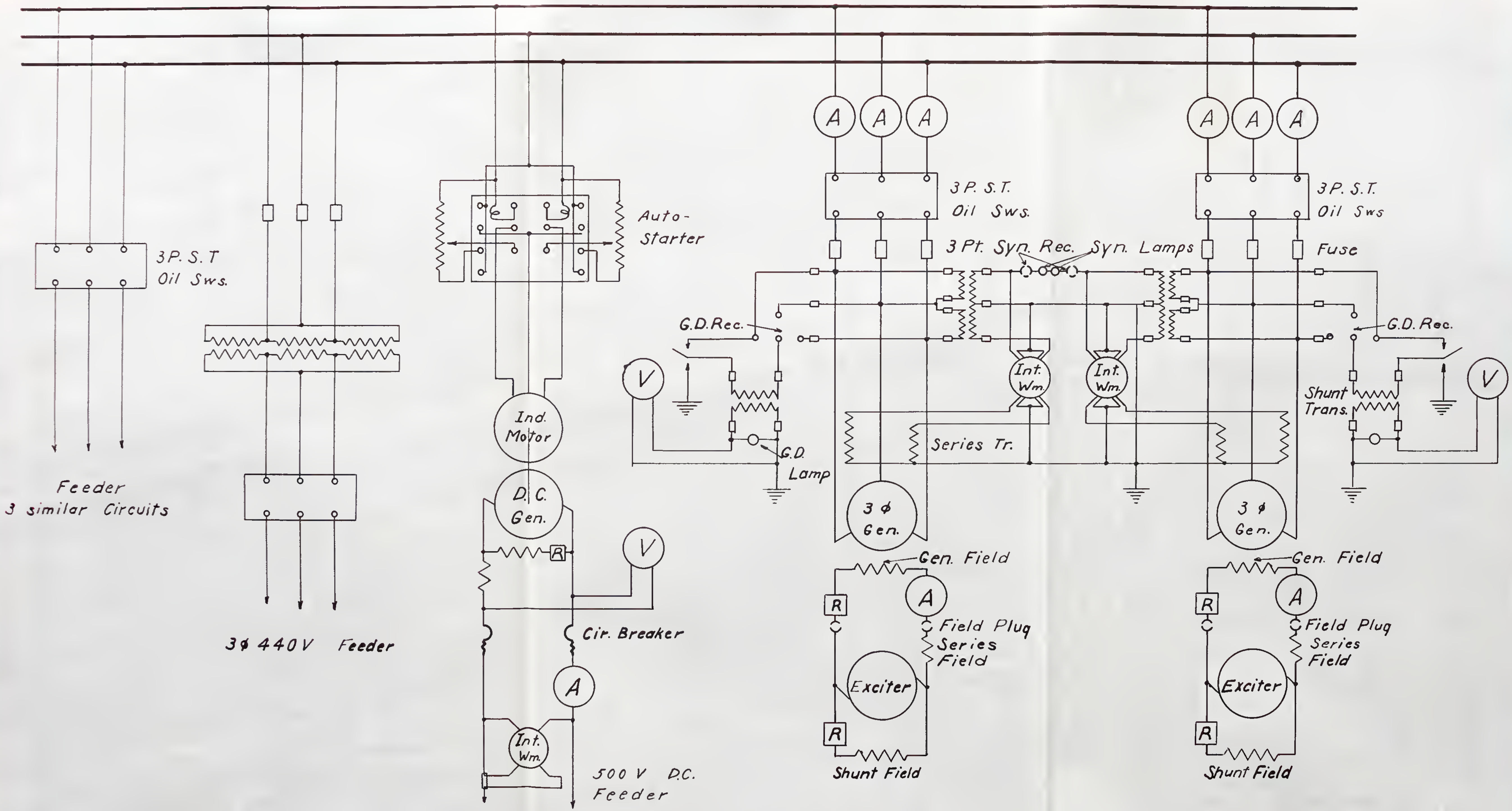


FIG. 7.– Diagram of Present Switch-board Connections.

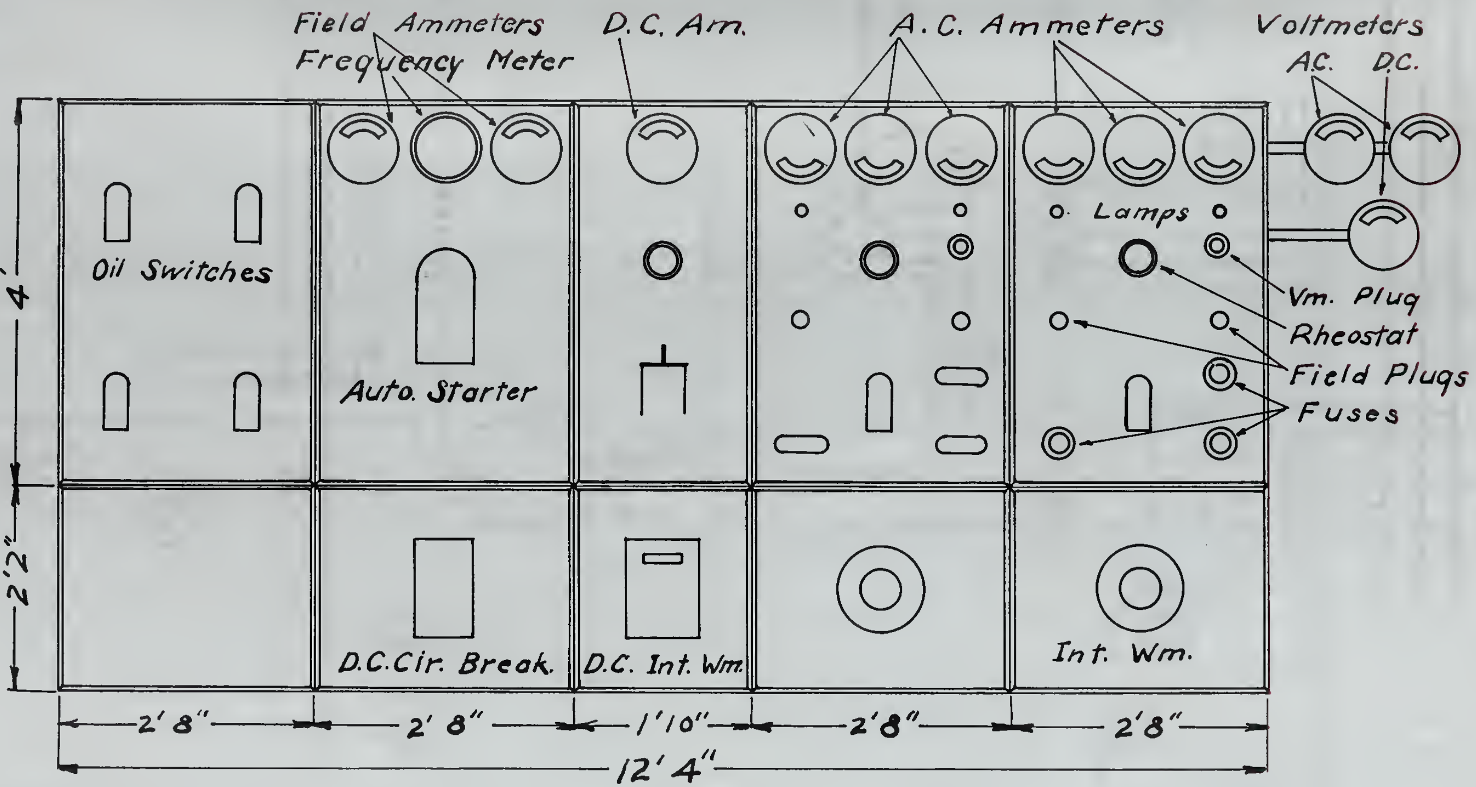
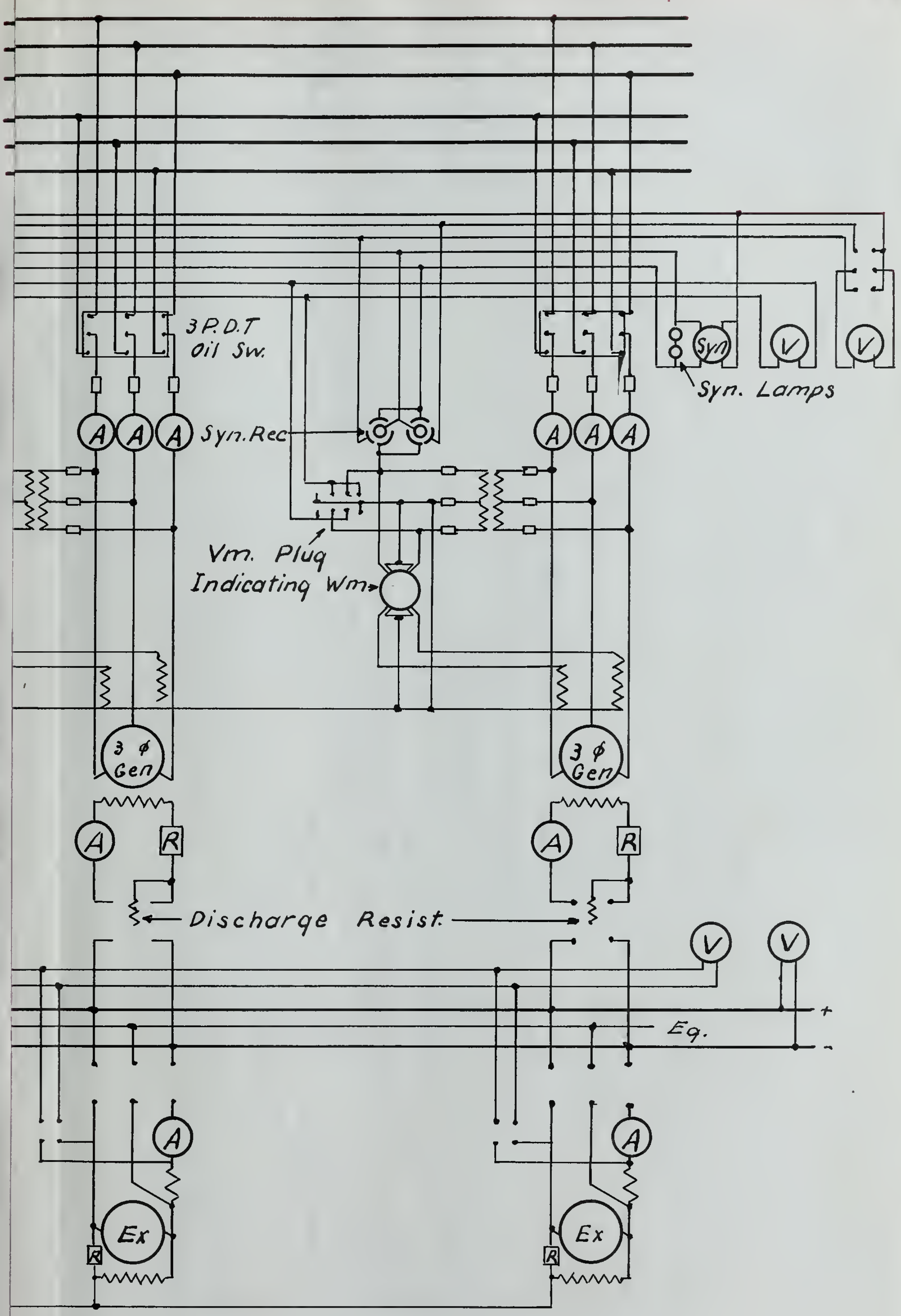


FIG. 8.- Elevation of Present Switchboard



3 P.D.T
Oil Sw.
Syn. Rec
Syn
Syn. Lamps
Vm. Plug
Indicating Wm
3 φ
Gen
Discharge Resist.
Eq.
Ex

ctions

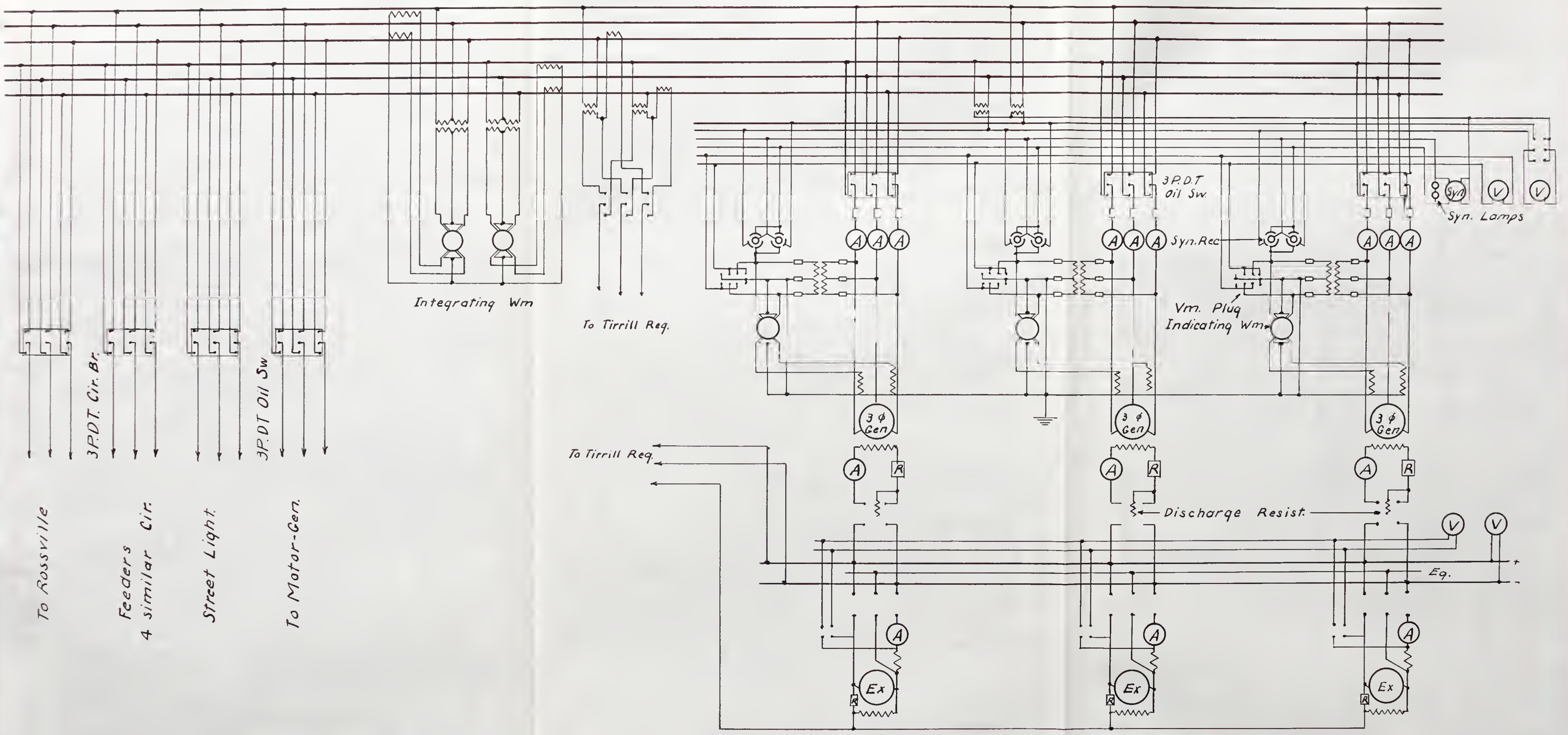
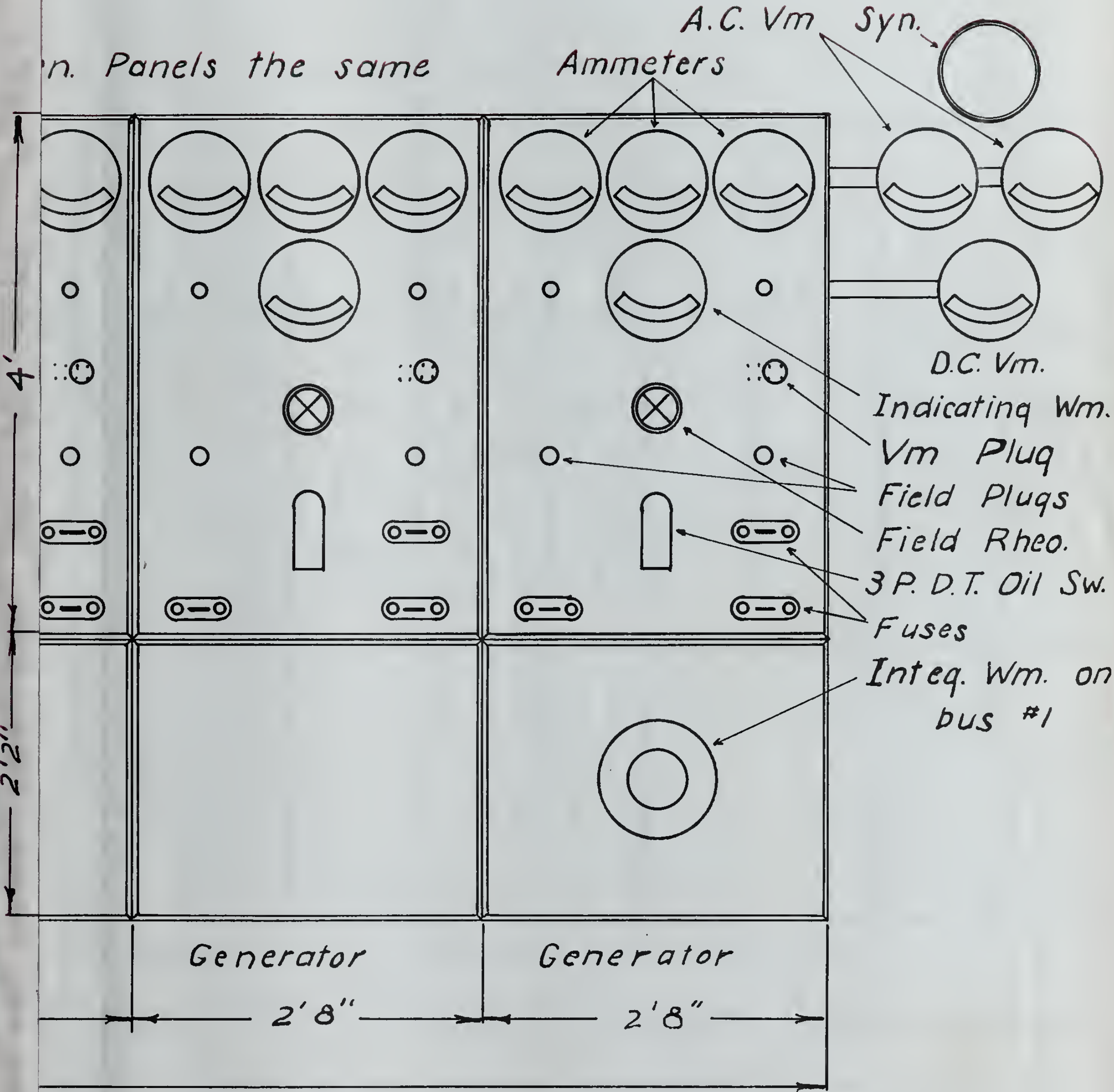


FIG. 9. - Diagram of Proposed Switchboard Connections

n. Panels the same



"= 16"

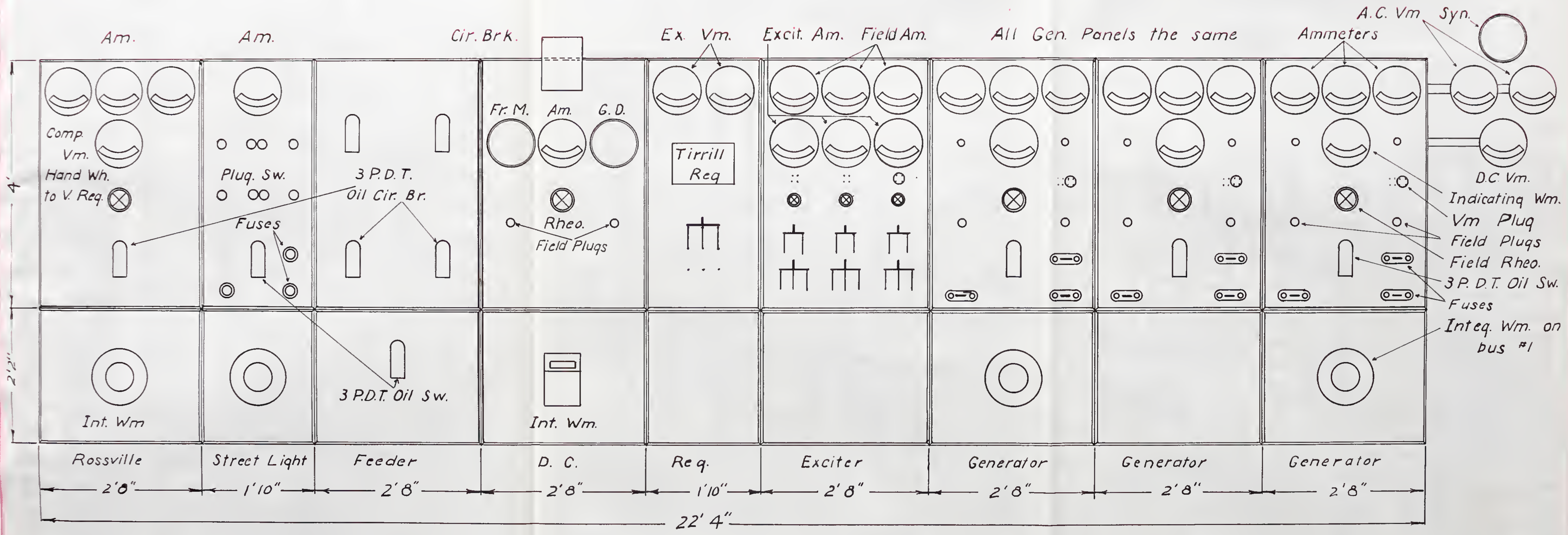


FIG. 10. - Elevation of Proposed Switchboard

Scale 1" = 16"

…EST No. I —

No.	Time	…	…ATED HORSE POWER: … Engine, Left Cylind.	Engine, Total	№ 2 Engine	OUTPUT IN K…: Meter No. 1 Reading Const. 20	Meter No. 2 Reading Const. 20	Tot… (Sum… No. 1… Time…)
1	4 30		SEE EXPLANATION OF DATA	244.5	-			
2	5 00			240.2		2.01	4.25	125
3	5 30			264.0		2.26	4.45	13…
4	6 00			280.8		2.51	4.25	13…
5	6 30			239.0		2.01	3.05	101
6	7 00			238.2		2.31	3.35	113
7	7 30			223.5		2.31	3.35	111
8	8 00			274.5		2.21	3.25	109
9	8 30			243.0		2.06	3.05	102
10	9 00			234.6		1.91	2.75	93
11	9 30			220.0		1.96	2.36	86
12	10 00			246.5		1.31	2.45	75
13	10 30			194.4		1.21	1.97	63
14	11 00				58.6	1.03	1.6	52
15	11 30				64.0	1.01	0.92	38
16	12 00				84.4	0.71	0.58	25
17	12 30				49.7	0.61	0.54	23
18	1 00				50.7	0.41	0.44	17.
19	1 30				51.0	0.43	0.65	21.
20	2 00				43.2	0.35	0.55	18
21	2 30				55.2	0.31	0.44	15.
22	3 00				48.2	0.36	0.53	17.
23	3 30				73.3	0.56	0.48	20.
24	4 00				71.2	0.81	0.53	26
25	4 30				73.9	0.86	0.49	27
26	5 00				60.5	0.22	1.50	35
27	5 30				95.4	0.29	1.50	35
28	6 00				965	0.51	1.88	47.
29	6 30				96.2	0.76	1.98	54
30	7 00				93.8	0.81	2.27	61.
31	7 30				103.4	0.71	1.98	53
32	8 00				110.5	0.76	2.28	60
33	8 30				110.5	0.51	2.18	53
34	9 00				107.8	0.51	2.08	51.
35	9 30				113.7	0.81	2.78	71.
36	10 00				110.6	0.61	2.58	63
37	10 30				114.9	0.71	2.67	67.
38	11 00				114.9	0.66	2.67	66
39	11 30				91.8	0.66	2.77	68
40	12 00				87.3	0.32	2.28	52
41	12 30				66.4	0.32	2.18	50
42	1 00				127.8	0.52	2.47	59
43	1 30				136.4	0.61	2.18	55
44	2 00	SEE EXPLAN-	ATION OF DATA	173.7		0.65	2.39	60
45	2 30			178.5		0.71	3.05	75.
46	3 00			163.0		0.71	3.15	77.
47	3 30			152.4		0.47	2.37	56.
48	4 00			145.8		0.71	2.65	67.
49	4 30			167.4		1.26	3.05	86
AVERAGES AN… NET QUANTITI…			108.5	214.3	85.4			66

General Data — Test No. I

No.	Time	Temperature in Degrees F. Outside	Room Prod.	Room Eng.	Ash Pits No. 1	Ash Pits No. 2	Gas Leaving Producer No. 1	Gas Leaving Producer No. 2	Water Entering	Water Leaving Jacket	Water Leaving Scrubber	Gas Leaving Dry Scrubber	Suction in Inches of Water Producer No. 1	Producer No. 2	Scrubber Wet	Scrubber Dry	Water Scrubber Meter No. 1 Cu. Ft.	Water Scrubber Meter No. 2 Gal.	Meter Reading Jacket Cu. Ft.	Coal Fired in Lbs.	Explosions per Min.	Mean Effective Pressure No. 1 Engine Right Cylind.	No. 1 Engine Left Cylind.	No. 2 Engine	Indicated Horse Power No. 1 Engine Right Cylind.	No. 1 Engine Left Cylind.	No. 1 Engine Total	No. 2 Engine	Output in K.W. Meter No. 1 Reading Const. 20	Meter No. 2 Reading Const. 20	Total (Sum of No. 1 & No. 2 Times 20)	Current in Amps. I_1	I_2	I_3	Mean	E.M.F. in Volts	Apparent Power ($\sqrt{3}EI$)	P.F. Power Factor	Remarks
1	4:30 P	23.0	54.0	69.0	143	140	390	320	52.0	106	78.0	59.5	.75	.75	3.5	4.75	2120	618	44276		176.6	45.3	See Explanation of Data		120.5	See Explanation of Data	244.5												
2	5:00	21.5	55.0	68.0	140	150	510	410	52.0	120	77.0	59.7	1.00	1.00	4.00	5.0	2150	756	44336		176.6	44.5			118.3		240.2		2.01	4.25	125.2	37.0	40.0	36.0	36.0	2460	153.2	.817	
3	5:30	18.7	64.0	68.5	162	180	580	480	52.0	114	79.0	60.0	.75	.75	3.5	5.0	2166	874	44389		175.4	49.3			130.0		264.0		2.26	4.45	134.2	36.0	42.0	38.0	38.7	2460	165.0	.813	
4	6:00	17.0	64.0	68.5	163	190	615	520	52.0	115	82.0	60.0	.60	.60	3.5	4.0	2183	988	44469		178.8	47.7			128.3		280.8		2.51	4.25	135.2	34.0	41.0	35.0	36.7	2480	157.6	.861	
5	6:30	16.0	67.0	68.0	164	196	620	520	51.0	114	79.0	61.0	.60	.60	3.3	3.5	2200	1117	44526		174.8	44.8			117.7		239.0		2.01	3.05	101.2	25.0	32.0	26.0	27.7	2440	117.2	.863	
6	7:00	15.6	67.0	68.0	164	201	620	612	52.0	119	82.0	61.0	.70	.70	3.0	3.7	2217	1235	44588		178.4	43.7			117.3		238.2		2.31	3.35	113.2	27.0	36.7	28.0	30.3	2440	128.1	.893	
7	7:30	14.0	71.0	68.0	165	206	638	620	52.0	116	82.8	61.0	.70	.50	3.25	3.6	2234	1352	44660		175.6	42.0			111.0		223.5		2.31	3.35	111.2	26.0	30.0	26.0	27.3	2480	117.3	.947	
8	8:00	14.0	70.0	68.0	164	208	654	640	52.0	121	83.0	61.8	.50	.70	3.4	3.6	2251	1476	44705		179.0	50.1			135.0		274.5		2.21	3.25	109.2	27.0	30.0	26.0	27.6	2500	118.5	.912	
9	8:30	14.0	65.6	67.5	163	208	650	652	52.0	116	83.0	61.8	.60	.60	3.3	3.7	2268	1598	44738		174.2	45.7			119.6		243.0		2.06	3.05	102.2	26.0	33.0	25.0	28.0	2440	118.3	.863	
10	9:00	14.0	69.0	66.5	164	208	654	656	52.0	114	82.4	62.0	.50	.60	3.0	3.5	2286	1728	44790		179.4	42.8			115.5		234.6		1.91	2.75	93.2	24.0	32.0	24.0	26.7	2440	112.8	.823	
11	9:30	12.5	66.0	67.0	164	208	646	656	52.0	122	82.0	62.0	.50	.60	3.0	3.5	2304	1852	44835		175.0	41.2			108.4		220.0		1.96	2.36	86.4	21.0	23.0	20.0	21.3	2520	92.9	.932	
12	10:00	13.0	65.0	66.5	171	206	643	660	52.0	117	82.0	61.8	.50	.50	3.0	3.5	2321	1972	44881		178.6	43.3			121.5		246.5		1.31	2.45	75.2	18.0	21.0	16.0	18.3	2560	81.2	.926	
13	10:30	12.0	63.0	66.5	170	201	440	438	51.5	117	79.0	61.5	.40	.50	2.5	3.25	2339	2100	44929	589	174.6	36.4			95.7		194.4		1.21	1.97	63.0	18.0	26.0	19.0	21.0	2420	88.1	.721	Fired Producers
14	11:00	12.5	61.5	66.0	167	201	400	408	52.0	116	68.0	61.0	.20	.20	1.7	1.8	2359	2244	44972	385	90.0			34.6				58.6	1.03	1.6	52.6	16.0	20.0	18.0	18.3	2420	75.5	.690	Changed from No. 1 to No. 2 Engine
15	11:30	11.8	62.5	66.5	166	200	410	406	52.0	114	62.0	60.5	.20	.20	2.0	2.25	2376	2355	44986		90.0			37.8				64.0	1.01	0.92	38.6	14.0	10.0	18.0	14.0	2380	57.8	.660	
16	12:00 M	10.2	58.0	66.0	164	196	406	388	51.2	111	61.0	60.0	.20	.20	1.7	1.75	2390	2470	45005		90.3			49.7				84.4	0.71	0.58	25.8	13.0	7.0	15.0	11.7	2380	48.7	.536	
17	12:30 AM	10.0	58.0	66.0	160	195	400	380	51.0	112	59.0	60.0	.20	.20	1.7	1.8	2410	2606	45026		91.1			29.0				49.7	0.61	0.54	23.0	12.5	6.0	14.0	10.8	2340	43.8	.524	
18	1:00	9.5	61.3	65.5	160	195	388	370	50.5	121	58.6	59.2	.20	.20	1.5	1.6	2427	2726	45042		93.0			29.0				50.7	0.41	0.44	17.0	6.6	6.0	7.0	6.5	2430	24.7	.621	
19	1:30	10.0	72.5	66.0	162	198	380	364	51.0	122	58.0	59.2	.20	.20	2.0	2.0	2445	2848	45058		91.9			29.5				51.0	0.43	0.65	21.6	7.0	7.4	8.0	7.5	2400	31.4	.692	
20	2:00	9.5	73.0	66.5	164	200	370	350	51.0	119	58.0	60.0	.20	.20	1.5	1.6	2462	2968	45073		93.3			24.65				43.2	0.35	0.55	18.0	6.7	6.4	7.2	6.8	2360	27.8	.648	Shut Coal Bin Door
21	2:30	9.2	73.0	66.0	164	199	368	364	50.3	117	57.5	60.5	.20	.20	1.6	1.7	2480	3095	45088		91.4			32.3				55.2	0.31	0.44	15.0	6.0	5.6	6.6	6.1	2390	25.2	.595	
22	3:00	9.0	73.0	66.0	164	199	370	362	50.0	116	57.0	61.0	.20	.20	1.7	1.8	2497	3215	45102		92.0			27.85				48.2	0.36	0.53	17.8	6.5	6.0	6.0	6.7	2370	25.4	.700	
23	3:30	11.0	75.5	66.0	164	199	384	370	51.1	117	58.0	61.0	.20	.20	1.8	1.9	2516	3345	45118		92.0			42.4				73.3	0.56	0.48	20.8	7.2	6.5	7.5	7.1	2440	30.0	.693	
24	4:00	12.2	74.5	66.0	163	198	386	380	51.0	119	58.0	61.0	.20	.20	1.8	2.2	2533	3467	45132		93.3			40.4				71.2	0.81	0.53	26.8	13.5	6.0	14.5	11.3	2370	46.3	.578	
25	4:30	14.0	75.0	66.0	162	198	380	362	50.5	120	59.0	62.0	.20	.20	2.0	2.0	2551	3594	45147	282	91.9			45.7				73.9	0.86	0.49	27.0	14.0	6.0	15.0	11.7	2370	47.8	.563	Fired Producers
26	5:00	14.8	75.0	66.0	159	195	370	384	51.0	122	60.0	61.8	.20	.20	2.2	2.3	2568	3710	45163		92.8			34.65				60.5	0.22	1.50	35.4	18.0	18.0	16.5	17.5	2310	70.0	.506	
27	5:30	16.8	76.0	67.0	161	188	390	410	51.3	111	61.0	62.0	.20	.20	2.5	2.7	2586	3837	45182		92.9			54.6				95.4	0.29	1.50	35.8	17.0	17.0	16.5	16.8	2340	68.2	.526	
28	6:00	17.0	76.2	67.0	162	186	426	430	51.2	119	61.0	63.0	.20	.20	2.7	2.9	2605	3970	45199		93.5			54.9				96.5	0.51	1.88	47.8	19.5	20.5	19.0	19.7	2330	79.5	.603	
29	6:30	18.2	77.3	68.0	164	185	456	452	51.0	126	63.0	63.0	.20	.20	3.0	3.2	2622	4090	45219		92.0			55.7				96.2	0.76	1.98	54.8	19.5	22.0	18.5	20.0	2330	80.8	.678	
30	7:00	18.2	78.0	68.0	164	184	470	466	51.0	121	63.0	63.0	.25	.25	3.0	3.5	2640	4215	45239		93.1			53.3				93.8	0.81	2.27	61.8	20.5	24.0	21.0	21.8	2290	86.4	.713	Shook Grates
31	7:30	19.0	78.0	70.0	165	189	465	460	51.0	126	64.0	63.0	.30	.30	2.9	3.1	2657	4335	45263		92.3			59.8				103.4	0.71	1.98	53.8	21.0	23.0	21.0	21.7	2270	85.3	.631	
32	8:00	19.0	79.0	70.0	164	188	470	470	51.8	119	64.0	63.0	.30	.30	3.0	3.6	2671	4468	45287		93.5			63.2				110.5	0.76	2.28	60.8	22.5	25.0	22.0	23.2	2160	86.7	.702	
33	8:30	19.8	79.0	71.0	163	185	462	464	51.5	121	64.5	63.0	.30	.30	2.8	3.4	2683	4611	45310		92.0			63.6				110.5	0.51	2.18	53.8	21.0	24.0	21.0	22.0	2240	85.3	.631	
34	9:00	20.0	79.0	71.0	164	184	468	474	51.0	122	64.5	63.0	.30	.35	2.9	3.4	2695	4751	45332		93.1			61.3				107.8	0.51	2.08	51.8	21.0	24.0	21.5	22.1	2240	85.7	.606	
35	9:30	21.0	79.8	71.0	164	184	516	504	51.5	128	66.0	63.0	.40	.50	3.5	4.3	2706	4890	45347		92.3			65.0				113.7	0.81	2.78	71.8	27.0	33.0	28.0	29.3	2110	107.1	.671	
36	10:00	21.0	81.0	72.0	163	183	498	484	51.2	115	68.0	63.0	.50	.60	3.75	5.0	2720	5031	45380		93.5			61.3				110.6	0.61	2.58	63.8	23.0	28.0	24.0	25.0	2250	97.5	.656	
37	10:30	21.0	81.0	73.0	163	181	520	510	52.0	107	70.0	63.0	.50	.60	3.75	4.75	2732	5177	45413		93.2			64.3				114.9	0.71	2.67	67.6	25.0	30.0	26.0	27.0	2190	102.5	.660	
38	11:00	22.0	82.4	73.5	164	180	526	512	51.3	108	70.0	63.0	.50	.60	3.70	5.0	2743	5303	45447		96.0			64.3				114.9	0.66	2.67	66.6	25.0	30.0	25.0	26.7	2210	102.2	.652	
39	11:30 A.M.	22.0	84.0	74.0	160	178	530	512	50.0	108	70.0	63.5	.50	.60	3.75	5.0	2754	5435	45480		95.1			51.5				91.8	0.66	2.77	68.6	27.0	32.0	27.0	28.7	2180	108.4	.635	
40	12:00 N.	22.0	84.0	75.0	160	180	490	492	52.0	116	70.0	63.8	.50	.40	3.0	3.8	2764	5570	45511		95.0			48.6				87.3	0.32	2.28	52.0	22.5	27.0	22.0	23.8	2270	93.5	.557	
41	12:30 P.M.	22.0	84.0	75.0	160	175	480	474	52.8	116	69.5	63.5	.50	.56	3.0	3.8	2774	5715	45542		95.0			37.5				66.4	0.32	2.18	50.0	22.0	26.0	21.0	23.0	2260	80.0	.556	
42	1:00	22.5	78.0	75.0	163	175	520	508	52.0	115	70.0	64.0	.45	.60	3.0	4.00	2783	5857	45567		95.5			71.6				127.8	0.52	2.47	59.8	24.0	29.0	25.0	25.0	2180	94.3	.634	
43	1:30	22.8	81.0	75.0	160	172	510	496	52.0	114	72.0	69.0	.40	.60	3.2	4.0	2792	6000	45594	283	94.3			75.3				136.4	0.61	2.18	55.8	23.0	25.0	24.0	24.0	2260	93.8	.596	Fired Producers
44	2:00	22.1	82.0	73.0	161	172	633	668	52.0	120	84.0	63.0	.50	.50	2.8	3.0	2801	6134	45627		176.2	32.3	See Explanation of Data		85.6	See Explanation of Data	173.7		0.65	2.39	60.8	24.0	27.0	24.0	25.0	2260	98.0	.620	Changed from No. 2 to No. 1 Engine
45	2:30	22.0	86.0	72.0	162	174	642	674	52.0	120	89.0	63.8	.50	.50	3.0	3.2	2810	6264	45674		176.2	33.2			88.0		178.5		0.71	3.05	75.2	26.0	31.0	29.0	28.7	2350	116.7	.644	
46	3:00	21.0	60.0	72.0	164	174	746	708	52.2	118	92.0	63.5	.50	.50	3.5	5.0	2820	6430	45716		176.2	30.3			80.3		163.0		0.71	3.15	77.2	26.0	32.0	30.0	29.3	2330	118.3	.652	
47	3:30	19.0	53.0	71.0	158	198	530	720	51.0	118	84.0	62.5	.50	.60	3.25	5.0	2827	6554	45757		176.2	28.3			75.0		152.4		0.47	2.37	56.8	19.0	27.0	25.0	23.7	2420	99.3	.573	Cleaned Fires – Shook Grates
48	4:00	19.0	50.0	72.0	144	172	460	440	51.5	116	89.0	61.0	.60	.70	3.5	4.0	2837	6703	45799		176.2	27.1			71.8		145.8		0.71	2.65	67.2	21.0	30.0	27.0	26.0	2410	108.5	.620	Pulled Ash-pits – Sliced from Top
49	4:30	19.0	46.0	71.0	144	180	300	284	51.3	125	81.0	61.0	.60	.70	3.5	3.7	2845.7	6836	45839	1503	176.2	31.1			82.4		167.4		1.26	3.05	86.2	21.0	30.0	26.0	25.7	2420	107.7	.803	Fired Producers
Averages and Net Quantities		16.32	70.9	69.07	161.5	188.5	493.6	483.4	51.46	116.8	71.1	61.75	.41	.441	2.77	3.34	725.7	6218	1563	3042	176.3 / 93.06	39.9	40.9	48.78	105.8	108.5	214.3	85.4			66.8								

-TEST No. 2

N	ATED HORSE POWER: GINE Nº 1, LEFT CYLINDER	GINE Nº 1, TOTAL	ENGINE Nº 2	OUTPUT: METER No. 1 READING CONST. 20	METE No. 2 READI CONST.
	61.5	146.0		0.82	2.4
	78.8	158.5		1.20	3.0
	66.5	159.8		1.79	3.3
	89.5	191.0		2.06	3.4
	117.7	215.2		2.42	3.4
	102.0	210.4		2.47	3.4
	106.9	233.4		2.38	4.2
	122.5	239.5		2.36	4.2
	124.3	243.7		2.31	4.2
1	111.5	214.5		2.46	4.0
1	115.4	215.9		2.36	3.7
1	119.6	217.4		2.27	3.5
1	107.0	192.2		1.97	2.9
1	105.0	182.2		1.57	2.6
1	83.7	165.0		1.20	2.2
1			65.6	0.77	1.31
1			70.0	0.68	1.31
1			53.4	0.63	1.2
2			60.5	0.63	1.31
2			46.8	0.37	0.5
2			42.8	0.44	0.5
2			48.2	0.42	0.4
2			42.8	0.37	0.4
2			42.8	0.37	0.42
2			38.7	0.42	0.4
2			49.0	0.54	0.5
2			45.7	0.46	0.50
2			45.4	0.54	0.5
3			49.6	0.54	1.11
31			65.2	0.54	1.31
3			88.7	0.82	1.3
3			71.8	0.64	1.31
3			80.8	0.40	1.10
3			83.5	0.35	1.01
3			44.0	0.30	1.01
37			53.4	0.35	1.01
3			40.3	0.35	1.01
3			61.3	0.25	0.91
40			87.2	0.11	0.91
41			46.0	0.16	0.86
42			43.9	0.16	0.86
43			59.3	0.16	0.81
44			46.5	0.11	0.81
45			29.0	0.07	0.81
46			57.5	0.13	0.8
47			58.0	0.11	0.8
48			66.9	0.11	1.1
49			61.5	0.11	1.0
AVE			49.8	0.11	1.01
NET	100.5	198.5	55.8		

General Data — Test No. 2

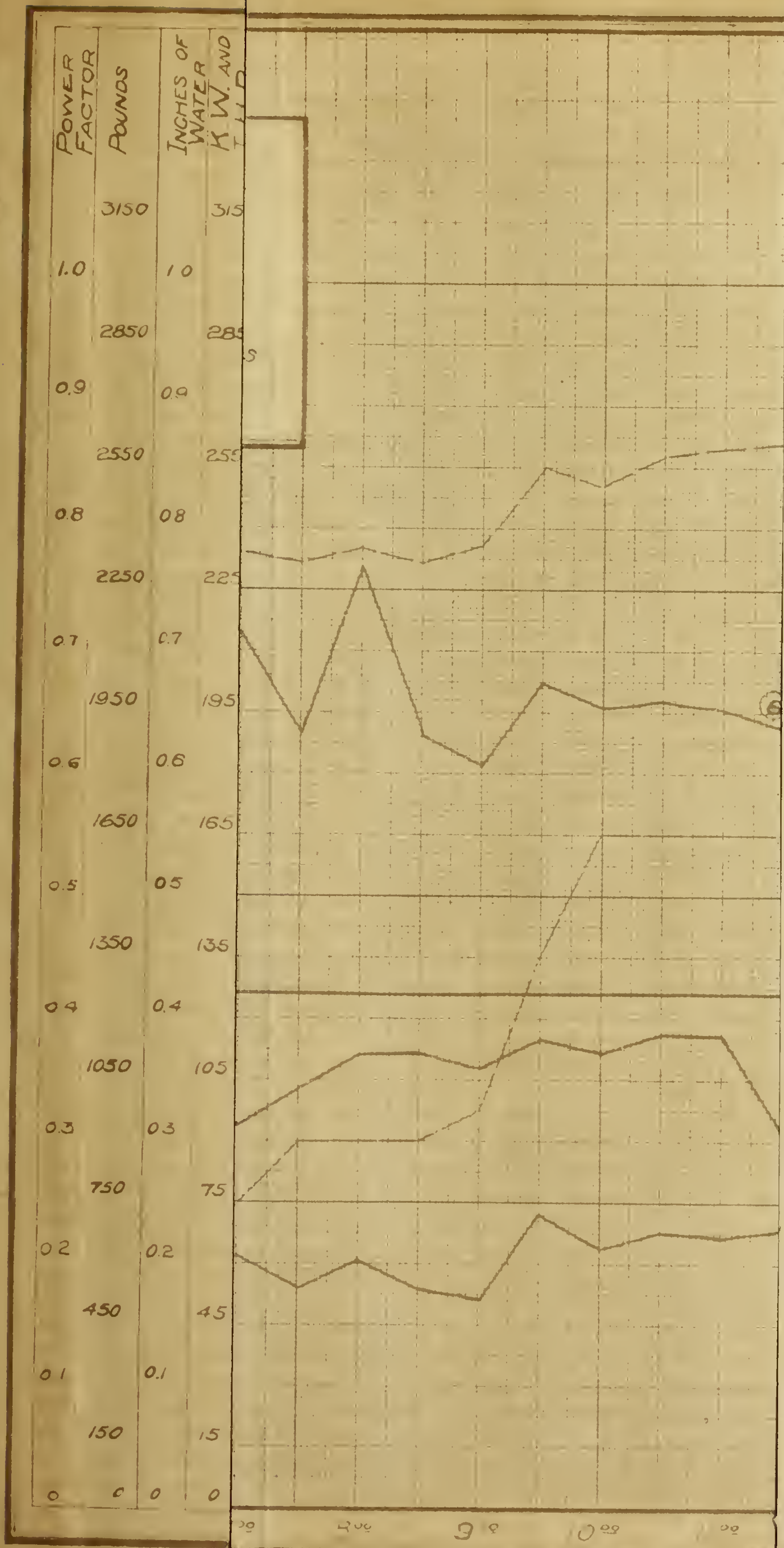
No.	Time	Temperature in Degrees F. — Outside	Room — Prod.	Room — Eng.	Ash Pits — No 1	Ash Pits — No 2	Gas Leaving Producer — No 1	Gas Leaving Producer — No 2	Water Entering	Water Leaving — Jacket	Water Leaving — Scrubber	Gas Leaving Dry Scrubber	Suctions Inches of Water — Producer No 1	Producer No 2	Scrubber Wet	Scrubber Dry	Water in Meter Readings — Scrubber Meter No 1 Cu. Ft.	Scrubber Meter No 2 Gal.	Jacket Cu. Ft.	Coal Fired in Lbs	Explosions per Min.	Mean Effective Pressure — Engine No 1 Right Cylinder	Engine No 1 Left Cylinder	Engine No 2	Indicated Horse Power — Engine No 1 Right Cylinder	Engine No 1 Left Cylinder	Engine No 1 Total	Engine No 2	Output in K.W. — Meter No. 1 Reading Const. 20	Meter No 2 Reading Const. 20	Total (Sum of No 1 & No 2 Times 20)	Current in Amps — I_1	I_2	I_3	Mean	E.M.F. in Volts	Apparent Power ($\sqrt{3}EI$)	P.F. Power Factor	Remarks
1	4⁰⁰ PM	35.0	58.0	67.5			366	360	54.0	107	83.5	58.0	.70	.70	3.8	4.0	3232.8	12987	47851		176	31.9	23.2		84.5	61.5	146.0		0.82	2.41	64.60	21.0	28.0	26.0	25.0	2390	103.5	.625	
2	4³⁰	31.0	72.0	67.0	139	164	342	380	54.0	103	83.0	58.5	.50	.50	3.0	3.7	3240.3	13098	47907		174.6	30.3	30.0		79.7	78.8	158.5		1.20	3.02	84.40	22.0	30.0	27.0	26.3	2340	107.0	.786	
3	5⁰⁰	31.0	76.0	68.0	148	184	390	486	54.0	109	81.0	59.8	.50	.50	2.8	3.4	3247.2	12314	47953		178.2	34.8	24.8		93.3	66.5	159.8		1.79	3.33	100.40	24.0	31.0	27.0	27.3	2420	114.5	.876	
4	5³⁰	30.2	80.0	69.0	156	192	432	540	53.5	112	82.0	61.0	.50	.50	3.0	3.5	3255	13325	48019		175.0	38.4	34.0		101.5	89.5	191.0		2.06	3.43	109.80	26.0	33.0	29.0	29.3	2420	123.0	.893	
5	6⁰⁰	30.5	82.0	67.0	163	199	484	574	53.0	109	87.0	62.0	.50	.60	3.2	4.0	3262	13440	48081		178.0	36.4	44.0		97.5	117.7	215.2		2.42	3.43	117.00	30.0	32.0	30.0	30.7	2460	131.0	.893	
6	6³⁰	30.5	86.0	67.0	168	201	522	587	53.0	111	87.0	63.5	.50	.60	3.2	3.5	3270	13554	48146		174.6	41.2	38.8		108.4	102.0	210.4		2.47	3.48	118.00	28.0	32.0	29.0	29.7	2460	126.8	.932	
7	7⁰⁰	30.5	88.5	68.0	172	204	563	612	53.0	110	89.0	65.0	.50	.60	3.0	4.0	3277	13672	48222		177.6	47.3	40.0		126.5	106.9	233.4		2.38	4.24	132.40	33.0	36.0	34.0	34.3	2460	146.0	.907	
8	7³⁰	30.5	91.0	67.0	171	203	591	642	53.0	107	93.0	66.0	.50	.60	3.2	4.2	3285	13783	48275		174.8	44.5	45.6		117.0	122.5	239.5		2.36	4.24	132.00	34.0	37.0	36.0	35.7	2460	151.5	.872	
9	8⁰⁰	30.5	93.0	69.0	174	205	606	642	53.0	110	94.0	67.5	.60	.70	3.3	4.0	3292	13899	48349		178.0	44.5	46.4		119.4	124.3	243.7		2.31	4.29	132.00	34.0	38.0	36.0	36.0	2460	153.5	.860	
10	8³⁰	30.5	86.0	68.0	175	179	630	672	53.0	107	94.0	69.0	.60	.70	3.3	4.3	3300	14005	48408		174.6	39.2	42.4		103.0	111.5	214.5		2.46	4.04	130.00	31.0	35.0	33.0	33.0	2480	141.6	.917	Opened Ashpit Doors
11	9⁰⁰	30.5	86.0	69.0	163	174	620	670	53.0	111	94.5	70.0	.60	.70	3.1	3.7	3306	14133	48481		174.4	38.4	44.0		100.5	115.4	215.9		2.36	3.79	123.00	28.0	33.0	31.0	30.7	2540	135.0	.910	
12	9³⁰	30.5	88.0	69.0	164	173	614	663	52.5	111	93.0	71.0	.50	.60	3.0	3.5	3314	14244	48548		173.0	37.6	46.0		97.8	119.6	217.4		2.27	3.53	116.00	27.0	31.0	29.0	29.0	2560	127.5	.910	
13	10⁰⁰	30.0	84.0	70.0	161	172	617	648	52.0	110	92.0	71.8	.50	.50	2.6	3.3	3322	14360	48617		177.8	31.9	40.0		85.2	107.0	192.2		1.97	2.92	97.80	24.0	26.0	22.0	24.0	2560	108.5	.902	
14	10³⁰	30.0	78.0	71.0	161	172	462	508	52.5	106	90.5	72.0	.50	.50	2.5	3.2	3329	14475	48687	1039	176.0	29.1	39.6		77.2	105.0	182.2		1.57	2.62	83.80	22.0	24.0	22.0	22.7	2560	100.5	.834	Sliced Fires from Top } 10¹⁵
15	11⁰⁰	30.5	74.0	71.0	158	166	426	474	53.0	100	84.0	72.2	.20	.20	2.0	2.4	3337	14619	48735		176.0	30.7	31.6		81.3	83.7	165.0		1.20	2.27	69.40	18.0	21.0	18.0	19.0	2580	84.8	.817	Fired Producers Closed Ashpit Doors
16	11³⁰	30.5	89.0	71.0	171	194	402	432	53.0	117	74.0	72.0	.20	.20	2.0	2.3	3345	14726	48778		92.0			37.9				65.6	0.77	1.31	41.60	14.5	16.0	15.5	15.0	2240	58.3	.713	Changed No 1 to No. 2 Engine
17	12⁰⁰ Mid.	32.5	87.0	73.0	174	196	400	432	52.5	119	67.5	72.5	.20	.20	2.0	2.2	3352	14835	48804		92.0			40.3				70.0	0.68	1.31	39.80	14.0	14.0	15.5	14.5	2360	59.3	.672	
18	12³⁰ AM	32.0	88.0	73.0	174	196	410	430	52.0	115	71.0	73.0	.20	.20	2.0	2.2	3359	14958	48817		92.0			30.9				53.4	0.63	1.21	36.80	13.5	13.5	14.5	13.8	2340	56.0	.657	
19	1⁰⁰	31.0	89.5	73.0	178	197	414	390	52.0	111	70.0	73.0	.20	.20	2.0	2.2	3366	15066	48839		91.8			35.1				60.5	0.63	1.31	38.80	13.5	14.5	15.0	14.2	2380	58.0	.669	
20	1³⁰	31.0	89.0	74.0	180	196	340	370	53.0	110	65.0	74.0	.15	.15	1.25	1.4	3378	15260	48859		92.9			26.7				46.8	0.37	0.50	18.6	7.0	6.5	7.0	6.8	2390	28.2	.660	
21	2⁰⁰	31.0	87.5	74.0	183	198	342	360	53.0	111	62.5	73.0	.20	.20	1.3	2.0	3382	15329	48887		91.7			24.8				42.8	0.44	0.52	19.20	7.0	6.5	7.0	6.8	2390	28.2	.681	
22	2³⁰	31.0	86.5	74.0	186	198	342	360	53.0	112	62.0	73.0	.20	.20	1.25	1.5	3390	15451	48903		93.0			27.6				48.2	0.42	0.42	16.80	6.5	6.0	6.5	6.3	2380	26.1	.644	
23	3⁰⁰	30.5	87.0	73.5	185	195	358	378	53.0	110	61.8	73.0	.20	.20	1.25	1.5	3400	15610	48920		95.0			23.9				42.8	0.37	0.42	15.80	6.5	5.6	6.1	6.1	2390	25.2	.628	
24	3³⁰	30.4	86.0	73.5	184	194	352	380	52.0	111	62.0	72.0	.20	.20	1.2	1.5	3407	15728	48940		95.3			23.9				42.8	0.37	0.42	15.80	6.3	5.5	6.0	5.8	2370	24.2	.654	
25	4⁰⁰	30.0	86.8	73.0	185	194	356	384	52.0	110	63.0	72.0	.20	.20	1.5	1.7	3414	15834	48958		95.3			21.6				38.7	0.42	0.44	17.20	6.5	5.5	6.9	6.2	2370	24.6	.694	
26	4³⁰	30.0	85.0	73.0	184	182	358	494	52.0	109	63.0	72.0	.20	.20	1.5	2.0	3422	15962	48989		91.4			28.5				49.0	0.54	0.56	22.00	8.0	6.5	7.5	7.3	2360	29.6	.743	
27	5⁰⁰	30.0	78.0	73.0	182	190	370	396	52.0	111	63.0	72.0	.20	.20	1.5	2.0	3430	16091	48997	175	92.2			27.4				45.7	0.46	0.50	19.20	7.0	6.0	6.7	6.6	2360	26.8	.716	Fired Producers
28	5³⁰	30.0	83.0	73.5	180	174	382	398	52.0	108	64.0	72.0	.50	.50	2.0	2.25	3437	16192	49015		92.6			26.1				45.4	0.54	0.56	22.00	7.0	6.0	7.2	6.7	2370	27.2	.809	
29	6⁰⁰	29.5	83.0	73.0	180	184	412	422	51.0	112	64.0	71.5	.40	.50	2.0	2.25	3445	16336	49036		91.6			28.8				49.6	0.54	1.11	33.00	12.5	12.5	12.0	12.3	2330	49.6	.666	
30	6³⁰	29.0	83.0	73.5	175	182	420	426	51.0	117	65.0	70.0	.50	.50	2.0	2.6	3452	16434	49053		91.6			37.8				65.2	0.54	1.31	37.00	14.0	14.5	14.0	14.2	2280	56.4	.656	
31	7⁰⁰	28.5	84.0	74.0	174	179	436	446	52.0	118	66.0	70.0	.50	.60	2.2	2.5	3458	16533	49070		92.5			51.0				88.7	0.82	1.35	43.40	15.0	15.5	15.0	15.2	2230	58.0	.748	
32	7³⁰	28.0	86.0	74.0	170	174	430	442	53.0	120	65.0	69.0	.50	.60	2.2	2.6	3466	16661	49090		91.8			41.7				71.8	0.64	1.31	38.80	14.5	14.0	14.5	14.3	2350	58.5	.669	
33	8⁰⁰	28.0	86.0	73.5	170	177	436	431	52.5	118	64.0	69.5	.50	.40	1.75	2.0	3477	16826	49106		92.1			46.7				80.8	0.40	1.10	31.00	13.0	12.0	12.0	12.3	2340	49.2	.622	
34	8³⁰	28.0	85.5	73.0	170	174	426	432	52.5	118	64.0	69.5	.50	.50	1.75	2.0	3483	16925	49123		92.0			48.3				83.5	0.35	1.01	27.20	12.0	11.5	11.5	11.7	2350	47.5	.573	
35	9⁰⁰	28.0	85.5	73.0	167	173	420	432	52.5	116	64.0	69.5	.50	.60	2.25	2.5	3491	17050	49141		92.5			25.3				44.0	0.30	1.01	26.20	11.0	11.0	10.5	10.8	2350	44.0	.596	
36	9³⁰	28.0	86.5	72.0	167	172	418	430	52.0	116	63.5	69.0	.20	.20	2.2	2.4	3498	17158	49159		93.5			31.4				53.4	0.35	1.01	27.20	11.0	11.0	10.5	10.8	2350	44.0	.618	
37	10⁰⁰	29.0	87.0	72.0	167	173	420	436	52.0	104	63.0	69.0	.15	.15	1.5	1.7	3507	17300	49176		92.5			23.2				40.3	0.35	1.01	27.20	12.0	11.5	11.0	11.5	2380	46.8	.581	
38	10³⁰	31.5	85.0	72.0	166	171	400	428	52.5	101	63.5	69.0	.15	.20	1.7	2.0	3515	17431	49199		92.1			35.4				61.3	0.25	0.91	23.20	11.0	10.5	10.0	10.5	2380	43.3	.535	
39	11⁰⁰	31.0	87.0	71.5	163	170	404	430	52.0	99	63.0	69.0	.15	.20	1.8	2.0	3522	17580	49220		92.4			50.2				87.2	0.11	0.91	20.40	10.5	10.5	10.0	10.3	2380	42.5	.480	
40	11³⁰	31.0	85.0	71.5	163	168	406	432	52.0	100	64.0 63.0	68.8	.20	.20	1.7	2.0	3530	17668	49242		92.6			26.4				46.0	0.16	0.86	20.40	10.5	10.5	10.0	10.3	2380	43.3	.470	
41	12⁰⁰ Noon	32.0	87.0	71.0	163	165	388	430	52.0	99	63.0	68.8	.15	.15	1.2	2.0	3537	17781	49263		91.6			25.5				43.9	0.16	0.86	20.40	11.0	11.0	10.5	10.8	2390	44.5	.458	
42	12³⁰ PM	32.0	87.0	71.0	162	165	400	416	52.0	103	63.0	68.5	.15	.15	1.2	1.5	3545	17917	49284		93.0			33.9				59.3	0.16	0.81	19.40	10.5	10.5	10.0	10.3	2400	43.3	.447	
43	1⁰⁰	30.0	86.0	69.0	166	167	396	388	52.0	104	63.0	68.7	.15	.15	1.75	1.5	3556	18080	49303	141	93.0			27.6				46.5	0.11	0.81	18.40	10.5	10.5	9.5	10.2	2390	42.5	.432	Fired Producers
44	1³⁰	29.0	83.5	69.0	163	166	392	408	51.5	102	63.0	68.0	.15	.20	1.5	2.0	3566	18221	49322		93.5			16.5				29.0	0.07	0.81	17.60	10.0	10.5	9.5	10.0	2390	41.4	.425	
45	2⁰⁰	29.0	83.0	67.0	163	166	390	412	51.0	102	63.0	67.5	.20	.20	1.5	2.0	3570	18285	49342		91.1			33.6				57.5	0.13	0.81	18.80	10.3	10.5	9.8	10.2	2390	42.2	.445	
46	2³⁰	29.0	74.0	68.0	161	165	390	410	51.5	103	63.0	67.0	.20	.20	1.6	2.0	3575	18362	49361		92.7			33.3				58.0	0.11	0.86	19.40	11.0	11.0	10.5	10.8	2360	44.7	.435	Cleaned Fires-Shook Grates
47	3⁰⁰	29.0	69.0	68.0	152	162	360	428	52.0	106	64.0	66.0	.20	.20	1.6	2.0	3585	18520	49371		92.0			38.7				66.9	0.11	1.11	24.40	12.5	13.0	12.0	12.5	2390	51.0	.478	Sliced from Top and Bottom
48	3³⁰	29.0	67.0	69.0	150	160	270	310	51.5	109	63.0	65.0	.30	.40	2.5	3.0	3589	18630	49397		92.5			35.4				61.5	0.11	1.01	24.40	11.0	11.5	11.0	11.2	2390	46.3	.526	Pulled Ashpits
49	4⁰⁰ PM	29.0	63.0	69.0	155	165	270	260	51.0	110	67.0	64.0	.30	.40	2.2	2.5	3598.4	18769	49417	1095.5	91.9			28.2				49.8	0.11	1.01	24.40	11.0	11.5	11.0	11.2	2390	46.3	.526	Fired Producers
Averages and Net Quantities		30.45	83.05	70.3	168.5	180.8	424	455.5	52.4	109.5	71.7	68.7	.335	.366	2.1	2.5	365.6	5782	1562.4	2450.5	175.8 / 92.30	37.07	38.03	32.16	98.0	100.5	198.5	55.8			52.85								

No 3 ——

No.	Ti[me]	Output in K.W. Meter No. 1 Reading Const. 20	Output in K.W. Meter No. 2 Reading Const. 20	Output in K.W. Total (Sum of No. 1 & No. 2 Times 20)	Current in [A] I_1	Current in [A] I_2	Current in [A] I_3
1	3[15]	0.15	0.82	19.40	11.5	11.0	10.5
2	3	0.18	0.79	19.40	10.8	10.4	9.6
3	4	0.23	1.06	25.80	11.5	12.0	11.2
4	4	0.80	1.45	45.00	15.0	16.0	15.0
5	5	1.14	1.98	62.40	18.7	19.5	17.5
6	5	1.23	2.04	65.40	19.0	20.5	17.8
7	6	1.25	2.46	74.20	23.7	25.7	21.6
8	6	1.41	2.43	76.80	24.9	25.3	22.8
9	7	1.49	2.36	77.00	25.7	25.2	23.1
10	7	1.52	2.36	77.60	26.4	25.6	23.0
11	8	1.41	2.36	75.40	26.2	25.6	23.4
12	8	0.71	2.00	54.20	21.5	23.7	21.0
13	9	0.61	1.88	49.80	19.3	20.6	18.0
14	9	0.52	1.83	47.00	20.8	21.0	19.0
15	10	0.37	1.76	42.60	18.5	19.2	17.4
16	10	0.32	1.64	40.20	18.5	19.5	17.7
17	11	0.17	1.44	32.20	16.5	17.0	15.8
18	11	0.12	1.49	32.20	16.2	17.0	15.8
19	12[15]	0.12	1.44	31.20	16.7	17.2	15.8
20	12	0.00	1.35	27.40	16.2	16.5	15.3
21	1	0.02	1.30	26.40	16.2	16.5	15.0
22	1	0.12	1.40	30.40	17.0	17.5	16.2
23	2	0.13	0.82	19.00	11.3	10.6	10.2
24	2	0.12	0.83	19.00	11.4	10.6	10.2
25	3	0.16	0.89	21.00	12.0	11.2	10.8
26	3	0.17	0.97	22.80	12.1	11.1	11.0
27	4	0.22	1.12	26.80	13.8	12.4	12.1
28	4	0.19	1.30	29.80	15.0	14.5	14.5
29	5	0.17	1.44	32.20	16.8	16.2	15.5
30	5	0.53	1.30	36.00	13.5	13.1	13.0
31	6	0.76	1.54	46.00	15.2	15.2	14.2
32	6	0.86	1.68	50.80	15.5	15.3	15.3
33	7	0.81	1.48	45.80	15.5	15.7	15.5
34	7	0.51	1.35	37.20	14.1	13.8	14.1
35	8	0.47	1.35	36.40	18.1	14.1	19.7
36	8	0.51	1.40	38.20	18.0	14.6	20.0
37	9	0.42	1.21	32.60	19.5	14.6	19.2
38	9	0.37	1.32	33.80	17.8	14.8	19.1
39	10	0.27	1.35	32.40	17.9	14.9	19.2
40	10	0.37	1.11	29.60	18.1	13.0	18.0
41	11	0.37	1.06	28.60	17.6	12.3	17.2
42	11	0.37	1.11	29.60	17.3	13.2	17.8
43	12	0.37	0.99	27.20	17.5	12.5	17.1
44	12	0.37	1.09	29.20	16.8	12.3	16.9
45	1	0.37	1.26	32.60	18.5	14.0	18.6
46	1	0.42	1.21	32.60	18.5	13.6	12.7
47	2	0.47	1.11	31.60	18.7	13.4	17.6
48	2	0.57	1.41	39.60	19.2	15.1	19.7
49	3	0.57	1.43	40.00	19.5	15.5	19.8
Averages a[nd] Mean Quantit[ies]				41.25			

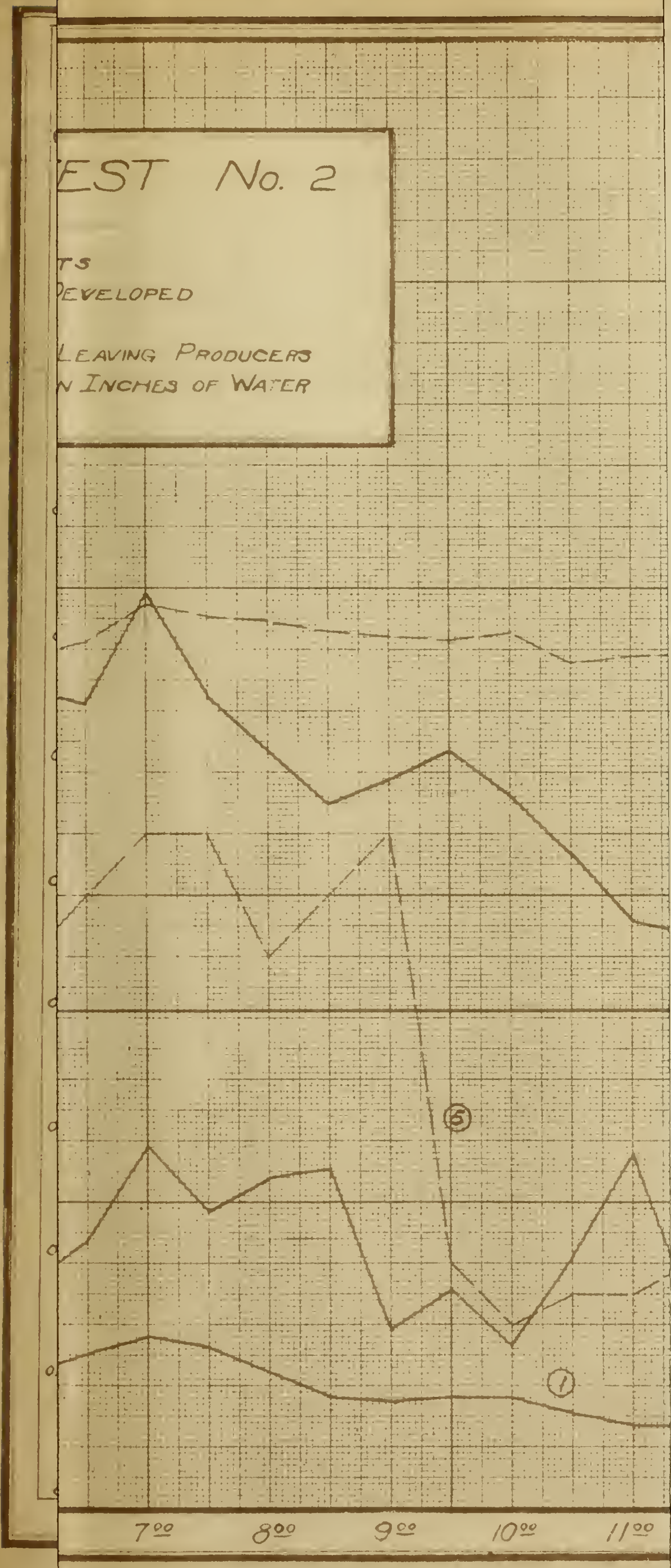
General Data — Test No 3

No	Time	Temp. °F Outside	Temp. Room Prod.	Temp. Room Eng.	Temp. Ash Pits No 1	Temp. Ash Pits No 2	Temp. Gas Leaving Producer No 1	Temp. Gas Leaving Producer No 2	Temp. Water Entering	Temp. Water Leaving Jacket	Temp. Water Leaving Scrubber	Temp. Gas Leaving Dry Scrubber	Suctions (Inches of Water) Producer No 1	Suctions Producer No 2	Suctions Scrubber Wet	Suctions Scrubber Dry	Water (By Meter Readings) Scrubber Meter No 1 – Cu. Ft.	Water Scrubber Meter No 2 Gal.	Water Jacket Cu. Ft.	Coal Fired in Lbs.	Explosions per Min.	M.E.P. Engine No 2 Lb. Sq. In.	I.H.P. Engine No 2	Output in K.W. Meter No. 1 Reading Const. 20	Output Meter No. 2 Reading Const. 20	Output Total (Sum of No 1 & No 2 Times 20)	Current in Amps. I_1	I_2	I_3	Mean	E.M.F. in Volts	Apparent Power ($\sqrt{3}EI$)	P.F. Power Factor	Remarks
1	3:15 P.M.	15.0	72.0	54	234	218	190	238	44.0	94	63.0	60.0	.20	.20	1.5	1.7	3837.6	22535	50422.5		92.5	19.2	33.4	0.15	0.82	19.40	11.5	11.0	10.5	11.0	2280	43.4	.447	
2	3:45	15.0	72.0	56	230	220	220	264	45.0	95	58.0	60.0	.20	.20	1.5	1.7	3844	22680	50447		93.7	23.4	41.2	0.18	0.79	19.40	10.8	10.4	9.6	10.3	2280	40.7	.476	
3	4:15	13.0	68.0	57	240	217	230	308	46.0	100	55.0	62.0	.40	.40	2.0	2.25	3851	22800	50470		94.4	25.8	45.7	0.23	1.06	25.80	11.5	12.0	11.2	11.6	2310	46.5	.555	
4	4:45	13.0	67.0	59	223	214	250	340	48.0	98	56.0	61.0	.40	.40	2.2	3.0	3858	22951	50495		92.6	47.4	82.4	0.80	1.45	45.00	15.0	16.0	15.0	15.3	2310	61.3	.733	
5	5:15	13.0	68.0	60	222	220	282	370	49.0	87	63.0	61.5	.80	.80	2.2	4.0	3864	23030	50530		94.5	61.3	108.9	1.14	1.98	62.40	18.7	19.5	17.5	18.6	2420	77.6	.804	
6	5:45	13.0	73.0	61	218	224	318	396	50.0	88	61.0	61.0	.80	.80	2.5	3.8	3872	23183	50574		93.5	56.2	98.8	1.23	2.04	65.40	19.0	20.5	17.8	19.1	2390	79.1	.826	
7	6:15	13.0	72.1	62	218	222	338	420	50.0	94	61.0	61.0	.80	.70	3.0	4.0	3879	23300	50612		95.3	66.0	108.4	1.25	2.46	74.20	23.7	25.7	21.6	23.7	2410	78.6	.751	
8	6:45	13.0	72.7	63	216	222	364	446	49.5	100	63.0	60.5	.30	.50	1.5	3.75	3885	23460	50654		93.0	54.0	94.4	1.41	2.43	76.80	24.9	25.3	22.8	24.3	2410	100.2	.763	
9	7:15	14.0	78.0	64	206	220	374	444	49.0	100	64.0	60.6	.30	.50	2.3	3.5	3891	23526	50680		92.5	50.8	88.8	1.49	2.36	77.00	25.7	25.2	23.1	24.7	2360	100.1	.765	
10	7:45	13.5	78.0	65	204	220	362	442	49.0	99	64.0	60.5	.40	.60	3.2	4.25	3897	23581	50727		92.5	51.0	88.7	1.52	2.36	77.60	26.4	25.6	23.0	25.0	2380	100.3	.770	
11	8:15	14.2	77.0	66	206	221	382	462	49.5	100	64.0	61.0	.30	.90	2.2	3.5	3904	23750	50776		93.1	55.7	97.5	1.41	2.36	75.40	26.2	25.6	23.4	25.1	2370	100.3	.750	
12	8:45	15.0	79.0	66	210	221	358	424	50.5	97	64.0	61.0	.30	.40	2.2	4.0	3911	23879	50808		94.2	48.6	86.0	0.71	2.00	54.20	21.5	23.7	21.0	22.1	2460	94.0	.577	
13	9:15	15.0	78.0	66	211	221	358	424	50.0	92	62.0	61.3	.30	.40	2.0	2.8	3917	23985	50854		95.5	36.6	65.7	0.61	1.88	49.80	19.3	20.6	18.0	19.3	2380	79.5	.626	
14	9:45	15.0	78.0	66	210	219	378	424	50.5	88	62.0	61.8	.30	.40	2.0	2.7	3923	24091	50879		92.3	42.6	74.2	0.52	1.83	47.00	20.8	21.0	19.0	20.0	2380	82.5	.570	
15	10:15	15.7	81.0	66	209	218	348	412	50.0	89	61.0	62.0	.20	.20	1.3	2.4	3930	24223	50918		93.7	40.2	70.8	0.37	1.76	42.60	18.5	19.2	17.4	18.4	2400	76.5	.557	Sliced Fires from Top (10:00 P.M.)
16	10:45	16.0	81.0	66	212	218	290	332	51.8	100	61.0	62.0	.20	.20	1.2	2.2	3936	24338	50945	699	92.5	27.3	47.7	0.32	1.64	40.20	18.5	19.5	17.7	18.6	2340	75.4	.533	Fired Producers
17	11:15	16.2	80.7	66	211	221	304	340	51.8	103	61.0	62.2	.20	.20	1.0	2.0	3943	24460	50967		93.7	23.7	41.7	0.17	1.44	32.20	16.5	17.0	15.8	16.5	2380	68.0	.474	
18	11:45	16.0	85.0	66	211	221	328	362	51.8	105	60.0	63.0	.20	.20	1.0	2.0	3950	24590	50998		92.6	27.0	47.2	0.12	1.49	32.20	16.2	17.0	15.8	16.4	2390	67.8	.475	
19	12:15 A.M.	16.0	84.0	66	211	219	340	362	51.8	104	59.0	63.0	.20	.20	1.0	2.0	3956	24719	51011		93.5	28.5	50.1	0.12	1.44	31.20	16.7	17.2	15.8	16.6	2390	68.6	.455	
20	12:45	16.0	81.8	66	210	220	346	360	51.8	101	59.0	64.0	.20	.20	1.0	2.0	3964	24846	51031		92.7	23.1	40.3	0.00	1.35	27.40	16.2	16.5	15.3	16.0	2390	66.2	.414	
21	1:15	16.0	82.0	66	208	220	360	374	51.0	100	59.5	64.0	.20	.20	2.0	2.5	3972	24902	51052		93.5	21.0	36.9	0.02	1.30	26.40	16.2	16.5	15.0	15.9	2400	66.0	.400	
22	1:45	16.0	81.0	66	206	219	354	390	51.0	100	59.5	64.5	.20	.20	2.0	3.0	3976	25077	51072		91.5	24.3	41.7	0.12	1.40	30.40	17.0	17.5	16.2	16.8	2360	68.7	.443	
23	2:15	16.0	81.0	67	218	223	356	380	51.0	100	59.5	64.0	.20	.20	2.0	2.5	3982	25200	51093		93.7	23.3	41.2	0.13	0.82	19.00	11.3	10.6	10.2	10.7	2370	43.9	.434	
24	2:45	17.5	81.0	67	204	218	360	380	51.1	100	59.0	64.5	.20	.20	2.0	2.5	3990	25324	51113		91.4	25.6	43.9	0.12	0.83	19.00	11.4	10.6	10.2	10.7	2380	44.1	.433	
25	3:15	17.5	81.0	67	212	218	320	330	51.1	105	59.0	64.5	.15	.15	2.0	2.5	3996	25411	51135		95.9	19.2	34.6	0.16	0.89	21.00	12.0	11.2	10.8	11.3	2410	47.2	.445	
26	3:45	17.0	81.0	64	208	218	348	326	50.0	104	58.0	65.0	.30	.30		2.1	4004	25582	51154		93.3	22.5	39.5	0.17	0.97	22.80	12.1	11.1	11.0	11.4	2400	47.4	.481	
27	4:15	17.5	80.0	67	208	219	324	332	51.0	103	59.0	65.0	.30	.40		3.25	4010	25700	51174	262	94.2	20.1	35.5	0.22	1.12	26.80	13.5	12.4	12.1	12.7	2370	52.0	.515	Fired Producers
28	4:45	17.5	81.0	67	204	218	340	358	51.1	102	60.0	65.0	.40	.50		3.0	4017	25820	51193		91.4	23.1	39.7	0.19	1.30	29.80	15.0	14.5	14.5	14.7	2400	61.0	.490	
29	5:15	17.0	83.0	66	203	218	330	354	51.1	103	60.0	65.0	.30	.40	2.1	3.0	4024	25935	51213		92.8	36.0	62.8	0.17	1.44	32.20	16.8	16.2	15.5	16.2	2380	66.8	.482	Shook Grates
30	5:45	13.0	83.0	66	208	218	360	370	50.2	107	61.5	65.0	.30	.40	2.1	3.0	4031	26075	51235		92.6	38.4	66.9	0.53	1.30	36.00	13.5	13.1	13.0	13.2	2460	56.2	.640	
31	6:15	13.0	82.0	66	204	218	374	370	50.2	112	62.0	65.0	.30	.40	2.2	3.0	4037	26200	51252		93.9	44.9	79.4	0.76	1.54	46.00	15.2	15.2	14.2	14.9	2460	63.5	.725	
32	6:45	9.0	81.1	66	200	218	380	390	50.2	119	63.0	65.0	.30	.40	2.4	3.0	4042	26285	51269		92.7	39.3	68.7	0.86	1.68	50.80	15.5	15.3	15.3	15.7	2370	64.2	.792	
33	7:15	8.0	82.0	66	200	220	390	396	50.7	102	63.0	65.0	.30	.40		3.2	4050	26435	51295		93.5	40.2	70.6	0.81	1.48	45.80	15.5	15.7	15.5	15.6	2500	67.5	.680	U Tube for Wet Scrubber Clogged
34	7:45	7.0	81.5	65	198	218	376	390	51.0	87	62.0	65.0	.30	.40		3.0	4056	26550	51332		91.7	50.4	86.9	0.51	1.35	37.20	14.1	13.8	14.1	14.0	2480	59.6	.630	
35	8:15	6.0	82.0	65	196	218	384	396	51.0	86	63.0	65.0	.30	.40		3.0	4061	26680	51371		93.1	31.4	55.0	0.47	1.35	36.40	18.1	19.1	19.7	17.3	2420	72.4	.503	
36	8:45	7.0	81.1	65	192	217	374	396	51.0	86	63.0	65.0	.30	.40		3.0	4068	26775	51407		92.6	34.0	59.2	0.51	1.40	38.20	18.0	14.6	20.0	17.5	2440	74.3	.513	
37	9:15	8.0	78.2	65	190	218	388	400	51.5	89	63.0	65.0	.30	.30		2.5	4074	26810	51441		92.6	35.1	61.2	0.42	1.21	32.60	19.5	14.6	19.2	17.8	2410	74.3	.439	
38	9:45	11.0	81.3	69	188	216	380	404	51.0	112	62.0	64.5	.30	.30		3.25	4081	27015	51472		92.6	40.7	72.6	0.37	1.32	33.80	17.8	14.8	19.1	17.2	2410	71.8	.470	
39	10:15	15.0	83.0	67	185	218	384	390	51.0	125	62.0	65.0	.30	.30		3.0	4088	27124	51482		92.6	42.1	73.4	0.27	1.35	32.40	17.9	14.9	19.2	17.3	2390	71.5	.453	
40	10:45	15.0	84.0	68	183	220	393	400	51.0	127	62.5	65.0	.30	.30		3.0	4094	27251	51497		92.6	37.6	65.4	0.37	1.11	29.60	18.1	13.0	18.0	16.4	2420	68.6	.431	
41	11:15	16.0	84.0	68	183	219	393	390	51.0	127	63.0	65.0	.30	.40		2.8	4098	27310	51513		92.7	35.1	61.2	0.37	1.06	28.60	17.6	12.3	17.2	15.3	2400	63.6	.450	
42	11:45	17.0	81.7	68	181	219	390	390	50.5	128	63.0	65.2	.20	.30		2.6	4108	27500	51524		92.5	42.2	73.3	0.37	1.11	29.60	17.3	13.2	17.8	16.1	2340	65.2	.454	
43	12:15 P.M.	19.0	90.0	69	179	218	380	396	51.0	129	62.5	65.0	.20	.20		3.0	4115	27610	51538		92.7	30.5	53.2	0.37	0.99	27.20	17.5	12.5	17.1	15.7	2380	64.8	.420	
44	12:45	23.0	85.6	69	176	220	382	396	51.0	130	62.0	65.0	.20	.20		2.75	4122	27674	51551		92.5	23.4	40.7	0.37	1.09	29.20	16.8	12.3	16.9	15.3	2380	63.0	.463	
45	1:15	27.0	83.0	69	176	219	390	430	51.0	121	62.5	65.0	.20	.20		3.0	4128	27850	51567	147	92.6	34.7	60.7	0.37	1.26	32.60	18.5	14.0	18.6	17.0	2390	70.3	.463	Fired Producers
46	1:45	28.0	86.0	69	173	217	400	406	51.5	127	64.0	65.0	.20	.20		2.5	4134	27977	51581		92.6	39.3	68.5	0.42	1.21	32.60	18.5	13.6	12.7	14.9	2420	62.5	.522	
47	2:15	35.0	88.0	69	171	218	412	384	51.0	120	64.0	66.0	.20	.20		3.0	4140	28129	51595		94.2	41.2	72.9	0.47	1.11	31.60	18.7	13.4	17.6	16.6	2450	70.6	.447	Opened Outside Door
48	2:45	38.0	60.1	69	171	219	412	402	51.0	122	64.5	66.6	.20	.20		2.8	4147	28229	51614		93.3	42.2	74.0	0.57	1.41	39.60	19.2	15.1	19.7	18.0	2400	74.8	.530	Cleaned Fires – Pulled Ashpits
49	3:15	40.0	52.0	69	183	218	296	408	51.0	132	67.0	65.0	.20	.20		3.3	4152.7	28338	51627	1168 4 P.M.	93.1	39.3	68.8	0.57	1.43	40.00	19.5	15.5	19.8	18.3	2410	76.4	.523	Fired Producers – 4 P.M.
Averages and Mean Quantities		16.27	78.9	65.4	205	219	348.6	383.9	50.3	103.5	61.5	63.55	.295	.339	1.86	2.86	315.1	5803	1204.5	2276	93.05	36.02	63.0			41.25								

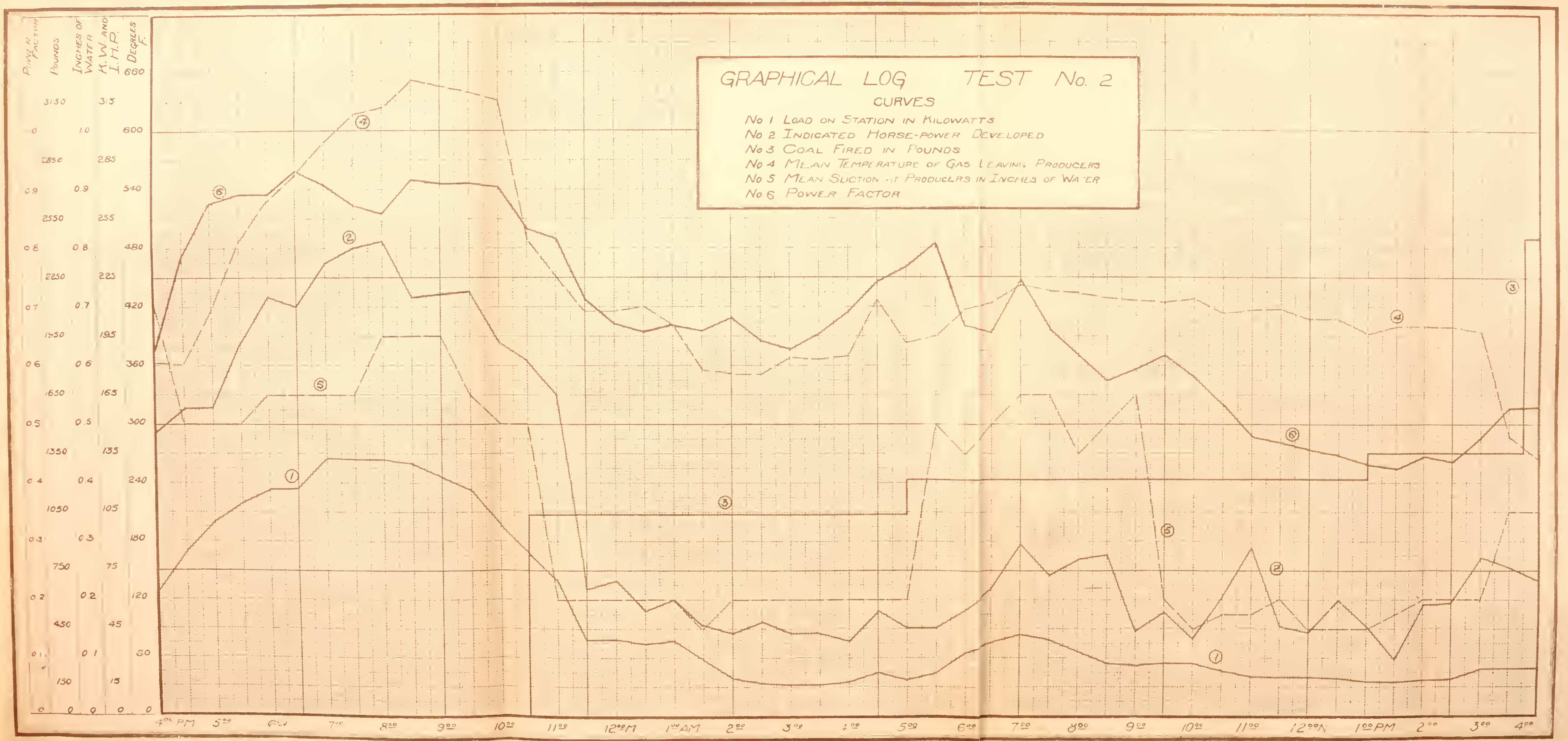


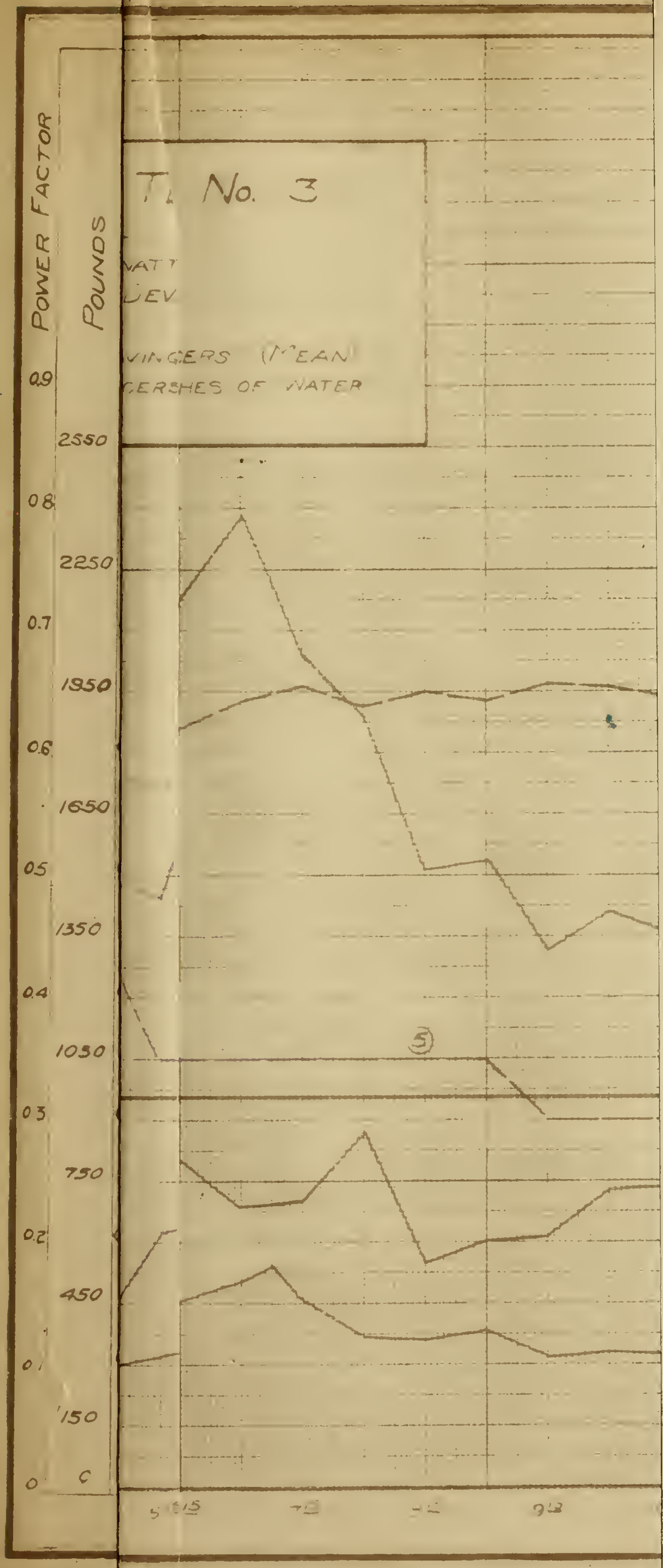
POWER FACTOR
POUNDS
INCHES OF WATER
K.W. AND
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3150
2850
2550
2250
1950
1650
1350
1050
750
450
150
315
285
255
225
195
165
135
105
75
45
15


GRAPHICAL LOG TEST No. 1
CURVES
No 1 LOAD ON STATION IN KILOWATTS
No 2 INDICATED HORSE-POWER DEVELOPED
No 3 COAL FIRED IN POUNDS
No 4 MEAN TEMPERATURE OF GAS LEAVING PRODUCERS
No 5 MEAN SUCTION AT PRODUCERS IN INCHES OF WATER
No 6 POWER FACTOR
POWER FACTOR
POUNDS
INCHES OF WATER
K.W. AND I.H.P.
DEGREES F
4 PM 6 7 8 9 10 11 12 M 1 AM 2 3 4 5 6 7 8 9 10 11 12 N. 1 PM 2 3



EST No. 2
TS
DEVELOPED
LEAVING PRODUCERS
N INCHES OF WATER
5
1
7^00
8^00
9^00
10^00
11^00


GRAPHICAL LOG TEST No. 2
CURVES
No 1 LOAD ON STATION IN KILOWATTS
No 2 INDICATED HORSE-POWER DEVELOPED
No 3 COAL FIRED IN POUNDS
No 4 MEAN TEMPERATURE OF GAS LEAVING PRODUCERS
No 5 MEAN SUCTION AT PRODUCERS IN INCHES OF WATER
No 6 POWER FACTOR
POWER FACTOR
POUNDS
INCHES OF WATER
K.W. AND I.H.P.
DEGREES F.
4 PM
5
7
8
9
10
11
12 M
1 AM
2
3
5
6
7
8
9
10
11
12 N
1 PM
2
3
4


POWER FACTOR
POUNDS
No. 3
WINGERS (MEAN
INCHES OF WATER
2550
2250
1950
1650
1350
1050
750
450
150
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5

GRAPHICAL LOG
No. 3
CURVES
No 2 INDICATED
No 4
No 5
SUCTION
No 6 POWER FACTOR
POWER FACTOR
POUNDS
INCHES OF WATER
K.W. AND I.H.P
DEGREES F

Diagram from Engine No. 2

Taken at 8:15 P.M., December 26, 1909.

M. E. P. 55.7 lb. per sq, in.

I. H. P. 97.5

Kw. load 75.4

Diagram from Engine No. 2

Taken at 3:45 A. M., December 27, 1909

M. E. P. 22.5 lb. per sq. in.

I. H. P. 39.5

Kw. load 22.8

F 611

No. Time Date Engine

At Cylinder Init. Pr. Exh. Pr. R. P. M.

End	End
Spring	Spring
Diag. Ar.	Diag. Ar
Mean Ord.	Mean Ord.
M. E. P.	M. E. P.
I. H. P.	I. H. P.

Indicator. Univ. of Illinois, Mechanical Laboratory. Observer.

Diagram from Left Hand Cylinder, Engine No. 1

Taken at 8:00 P. M., December 24, 1909

M. E. P. 46.4 lb. per sq. in.

I. H. P. 124.3

Kw. load 132

F 611

No. Time Date Engine

At Cylinder Init. Pr. Exh. Pr. R. P. M.

End	End
Spring	Spring
Diag. Ar.	Diag. Ar
Mean Ord.	Mean Ord.
M. E. P.	M. E. P.
I. H. P.	I. H. P.

Indicator. Univ. of Illinois, Mechanical Laboratory. Observer.

Diagram from Right Hand Cylinder, Engine No. 1

Taken at 8:00 P. M., December 24, 1909

M. E. P. 44.5 lb. per sq.in.

I. H. P. 119.4

Kw. load 132

Pump Diagram. Engine No. 1, R. H. Cylinder

Scale of Spring, 10 #

Pump Diagram. Engine No. 1, L. H. Cylinder

Scale of Spring, 10#

Pump Diagram. Engine No. 2

Scale of Spring, 10#